Defense Science and Technology Strategy

Director of Defense Research and Engineering

July 1992

THE DOD SCIENCE AND TECHNOLOGY STRATEGY

EXECUTIVE SUMMARY

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Executive Summary

A. MAINTAINING MILITARY TECHNOLOGICAL SUPERIORITY

U.S. cold war defense and weapons acquisition strategies were strongly driven by the competition with an adversary who possessed an ever-improving military juggernaut supplied by an active weapons system acquisition pipeline. The new defense and acquisition strategies focus on the potentially dangerous regional challenges we face, while retaining the capability to respond to any emerging global threats.

In addressing these challenges, the military equipment we face will often be of very high quality, providing our opponents with a formidable fighting capability. Regional powers have increasing access to both western weaponry and high quality equipment from the former Soviet Union. The U.S. will have to continue to work hard to maintain a significant technological edge.

In peace, technological superiority is a key element of deterrence. In crisis, it provides a wide spectrum of options to the National Command Authority and Commanders in Chief, while providing confidence to our allies. In war, it enhances combat effectiveness and reduces the loss of personnel and equipment, as was demonstrated by the performance of our weapons and supporting systems against Iraq. Advancing military technology continues to be a national security obligation.

B. THE NEW SCIENCE AND TECHNOLOGY STRATEGY

To carry out his responsibilities, the Director of Defense Research and Engineering (DDR&E) has formulated a new Science and Technology (S&T) strategy. The core of this strategy is to (1) provide for the early, intensive, and continued involvement of warfighters, (2) fuel and exploit the information technology explosion, and (3) conduct extensive and realistic technology demonstrations.

1. Involvement of Warfighters

A key element of the S&T strategy is the early and continued involvement of the users of technology. The strategy stresses the importance of feedback from the warfighters in providing concepts, doctrines, and military needs to the developers of technology and systems. It also stresses the "feed-forward" of new technology and systems from the developers to the operators.

These feedback and feed-forward loops will take place on a much expanded and integrated set of instrumented training ranges and electronic battlefields. "Synthetic environments" are being networked throughout the scientific and development communities to bring developers, scientists, engineers, manufacturers, and warfighters together to address and solve their most pressing problems.

2. Information Technology Explosion

The S&T strategy seeks to promote and leverage the information technology explosion, adapting and converting it into military technologies that will revolutionize military operations. This explosion has been fueled by the exponential increase in the speed and capacity of modern computers.

Together with the development of increasingly capable computer networks, these advances are creating enormous opportunities for the design of better and more affordable systems, the training of more qualified personnel, and the creation of more effective command, control, communications, and intelligence (C3I) structures. The information revolution also will enhance the use and value of distributed simulation systems and exercises that involve the military user directly and intimately in the development process.

3. Advanced Technology Demonstrations

A central tenet of the S&T strategy is that technology will be guided toward specific capabilities that can be proven with an Advanced Technology Demonstration (ATD). Such a demonstration of capability, coupled with simulations and exercises, will help to ensure that the technology is ready, manufacturing processes are available, and operating concepts are understood before a formal acquisition program is undertaken.

There generally are two types of ATDs—those focused on new system and subsystem concepts, and those focused on "enabling" technologies. These demonstrations of capability, coupled with advanced simulation techniques, will lead to comprehensive assessments of technical feasibility, affordability, and operational utility.

Technology demonstrations do not represent a new concept. The Have Blue aircraft, for example, demonstrated that stealth was practical in a flying aircraft prior to the F-117. Assault Breaker demonstrated technologies that went into both the JSTARS (Joint Surveillance and Target Acquisition Radar System) and ATACMS (Army Tactical Missile) programs. The MIMIC (Millimeterwave and Microwave Monolithic Integrated Circuits) program has demonstrated the ability to produce low-cost microwave integrated circuits for a wide variety of applications.

What is new is the scope and depth of the technology demonstrations, their central position in the acquisition process, and the emphasis on ultimately demonstrating useful military capabilities. Each Advanced Technology Demonstration will be designed to satisfy acquisition decision makers that the technology is feasible, affordable, and compatible with the operational concepts and force structure envisioned for the base force.

C. PROVIDING FOCUS—SEVEN S&T THRUSTS

To provide the focus for the S&T program, seven Thrusts have been defined that represent the demands being placed on the S&T program by the users' most pressing *military and operational* requirements. While there are goals and activities in the S&T program that fall outside of these Thrusts, it is crucial to the success of the S&T program that investments be focused on those efforts which show the greatest promise for improving future military capabilities, rather than simply providing a "balance" across all possible investment options. Focus, not balance, is the watchword of the new S&T strategy. The seven Thrusts are:

1. **Global Surveillance and Communications.** The ability to project power requires a global surveillance and communications capability that can focus on a trouble spot, surge in capacity, and respond to the needs of the commander.

2. **Precision Strike.** The desire for reduced casualties, economy of force, and fewer weapons platforms demands that we locate high-value, time-sensitive fixed and mobile targets and destroy them with a high degree of confidence within tactically useful timelines.

3. **Air Superiority and Defense.** The need to defend deployed military forces from aircraft and ballistic and cruise missiles, and to maintain our current decisive capabilities in air combat, interdiction, and close air support, requires a strong effort in missile defense and air superiority.

4. **Sea Control and Undersea Superiority.** The need to maintain overseas presence, conduct forcible entry and naval interdiction operations, and operate in littoral zones presupposes a strong capability in sea control and undersea warfare.

5. **Advanced Land Combat.** The ability to rapidly deploy our ground forces to a region, exercise a high degree of tactical mobility, and overwhelm the enemy quickly and with minimal casualties in the presence of a heavy armored threat and smart weaponry requires highly capable land combat systems.

6. **Synthetic Environments.** A broad range of information and human interaction technologies must be developed to synthesize present and future battlefields. We therefore must synthesize factory-to-battlefield environments with a mix of real and simulated objects and make them accessible from widely dispersed locations. Integrated teams of users, developers, and/or testers will be able to interact effectively. Synthetic environments will prepare our leaders and forces for war and will go with them to the real battlefield.

7. **Technology for Affordability.** Technologies that reduce unit and life cycle costs are essential to achieving significant performance and affordability improvements. Advances are

particularly needed in technologies to support integrated product and process design, flexible manufacturing systems that decouple cost from volume, enterprise-wide information systems that improve program control and reduce overhead costs, and integrated software engineering environments.

Within each Thrust, specific ATDs are being identified that are requisite to meeting the goals established for that Thrust. Detailed roadmaps to guide their progress also are being developed. The technologies that are exploited in these ATDs are derived from exploratory development programs (budget category 6.2), which in turn build on new knowledge derived from the basic research program (6.1). The management challenge is to tie these different programs together in an efficient way.

D. TECHNOLOGY MANAGEMENT

1. Research (6.1)

The Department of Defense conducts an aggressive program of research (budget category 6.1) in order to ensure that both cutting-edge scientific discoveries and the general store of scientific knowledge are optimally utilized in the development of superior military equipment, strategies, and tactics.

At a funding level approaching $1 billion annually, DoD research accounts for eight percent of total federal research funding and five percent of total national research funding (federal, state, and private industry). Thus, while DoD research funding is a significant component of national R&D, it is not the dominant component. As a consequence, the focus is on selected areas of critical importance to DoD that are not adequately addressed elsewhere. The 6.1 program is, for example, a major source of basic research support in electrical engineering, materials science, applied mathematics, and computer science, all of which are of particular importance to DoD.

2. Exploratory Development (6.2)

The role of the exploratory development program is to ensure that, as technological advances appear, they are investigated for possible inclusion in the ATDs in the seven Thrusts. To manage this process, 11 Key Technology Areas have been identified (definitions for each are provided on page I-22):

1. Computers
2. Software
3. Sensors
4. Communications Networking
5. Electronic Devices
6. Environmental Effects
7. Materials and Processes
8. Energy Storage

9. Propulsion and Energy Conversion
10. Design Automation
11. Human-System Interfaces

New technology applications that are successfully proven in these Key Technology Areas may apply to several or all of the seven Thrusts; an obvious example is advancements in computers. Each of the 11 Key Technology Areas has been assigned to a Senior Technologist who reports to the Deputy Director of Defense Research and Engineering (Science and Technology). The Senior Technologists are responsible for ensuring that the technologies required by the ATDs in each of the Thrusts are being properly pursued within the Service and Agency programs.

3. Thrust Areas (6.3A)

At the core of the S&T strategy is the imperative to develop and make available to the military forces new and advanced technologies that will ensure the long-term superiority of U.S. forces. This is why the strategy has been built around the seven Thrusts; these are crucial *military* capabilities which the S&T program must support.

The primary responsibility for guiding and overseeing each Thrust has been assigned to a Thrust Leader, who reports directly to the DDR&E. The Thrust Leaders' responsibilities are to oversee and coordinate those Service and Agency programs that bear on each Thrust, with the primary emphasis on Advanced Technology Demonstrations (ATDs) in the advanced development (budget category 6.3A) program. The actual execution of the program is left to line managers in the Services and Agencies.

Within the DDR&E organization, therefore, there is a matrix organization in which the Thrusts (Thrust Leaders) are supported by the Key Technology Areas (Senior Technologists). This is explained more fully on page I-26. A more detailed treatment of the S&T management processes being implemented by the DDR&E is contained in other documents.

E. MEETING MILITARY NEEDS

The goal of the seven Thrusts is to ensure the availability and integration of advanced technologies to meet military needs. To accomplish this goal, the management philosophy underlying the S&T Strategy emphasizes meeting the needs of the customer—"requirements pull"—while at the same time making available to the customer new technologies to meet pressing operational problems—"technology push." The strategy and management structure outlined above are designed to coordinate the interactions of all elements of the S&T program in order to maintain the technological superiority of our military forces.

I. BACKGROUND AND OVERVIEW

I. Background And Overview

1. Technology and National Military Strategy
2. Cold War Defense Strategy
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   - Acquisition
4. The New S&T Strategy
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1. Technology and National Military Strategy

The Science and Technology Strategy. This document presents the strategic plan for the Defense Department's Science and Technology program. It forms the basis for decisions and actions and provides the foundations for long- and short-range planning. Section I explains how changes in the world security environment have affected the requirements placed on the S&T program through changes in U.S. force structure and military and operational strategies. In particular, it explains how the S&T program is affected by (1) improvements in the information and communications flows between the S&T and "user" (warfighting) communities, (2) the revolution in information technology, and (3) the increased role of Advanced Technology Demonstrations (ATDs).

Section I explains the new emphasis being placed on seven major areas of military capability—the "Seven Thrusts"—and the management changes that will ensure the successful implementation of the strategy. Details on each of the Thrusts are provided in Section II.

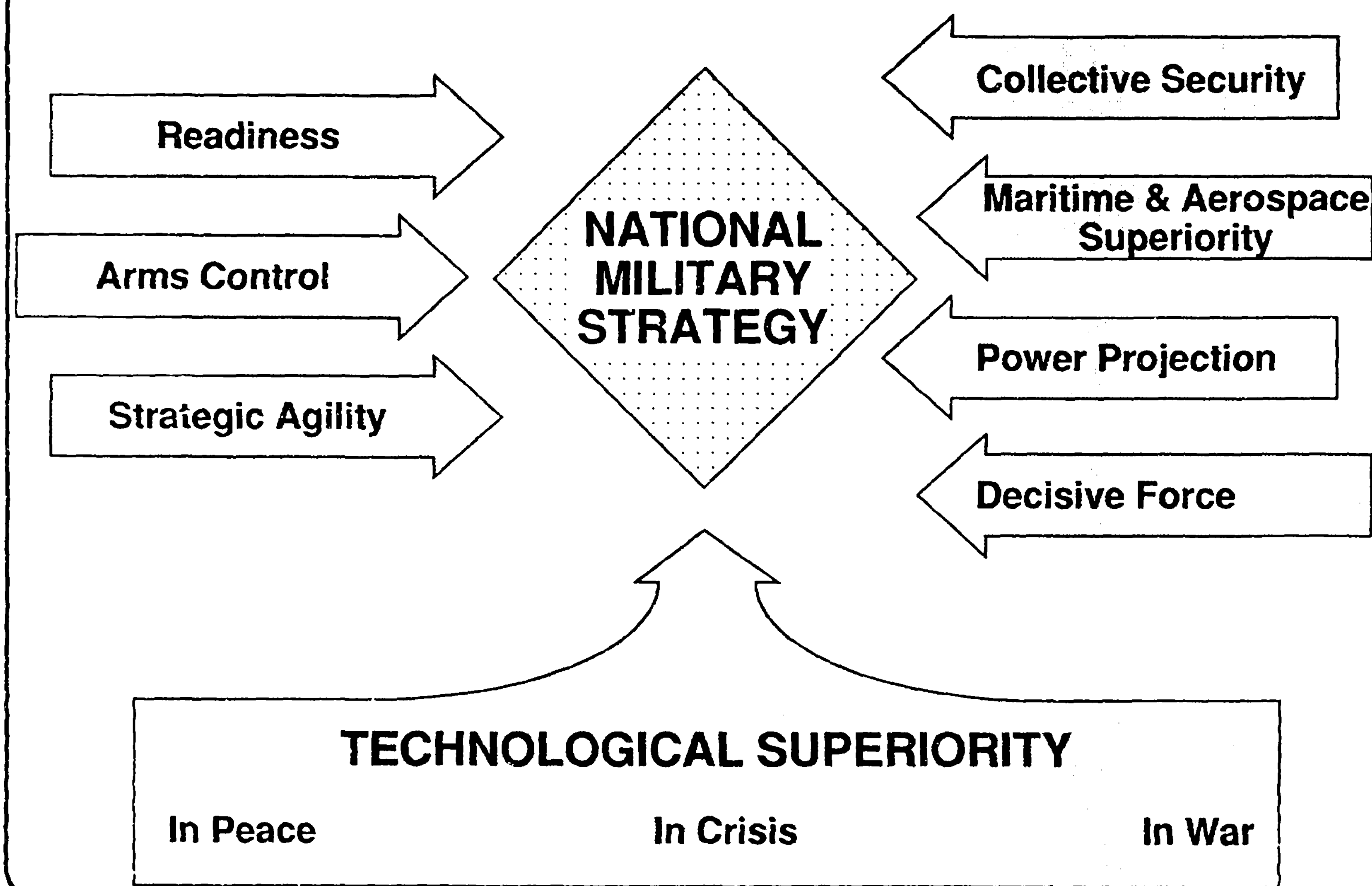
The Science and Technology Program. The Director of Defense Research and Engineering (DDR&E) takes the lead in the development of, and has decision authority over, all major aspects of the Science and Technology program. The Deputy Secretary of Defense has instructed the DDR&E "to direct the Secretaries of the Military Departments and heads of other components of the Department of Defense, when necessary with respect to all activities supported by funds [from budget categories 6.1, 6.2, and 6.3A]," and to "exercise oversight of and provide support for the technological aspects of the activities of the Strategic Defense Initiative." Thus, while the strategy is executed by the military departments and defense agencies, it is done so under the guidance and direction of the DDR&E.

The monies invested in science and technology by the military departments and defense agencies (other than SDIO) totaled $6.3 billion in fiscal year 1992. Investments by the Strategic Defense Initiative Organization (SDIO) were $5.1 billion. The total S&T investment for FY 1992 was thus $11.4 billion. The total of IR&D (Independent Research and Development) investments incurred by industry in 1991 was approximately $7 billion.

Commitment to Technological Superiority. The S&T strategy is imbedded in and aligned with the President's National Security Strategy, U.S. National Military Strategy, and the Defense Department's revised acquisition strategy. Technological superiority is one of the eight principles, articulated in the *National Military Strategy (1992)*, that capitalize on our enduring strengths and allow us to exploit the weaknesses of our potential adversaries. The United States must rely on a strong research and development establishment to provide the systems that reduce the risks to our forces and those of our allies and enhance the potential for the swift, decisive, and economical termination of conflict, with minimal casualties, on favorable terms.

In peace, technological superiority is a key element of deterrence. In crisis, it provides a wide spectrum of options to the Commanders in Chief (CINCs) and the National Command Authority. Our technological superiority also gives confidence to our allies. In war, it enhances combat effectiveness and reduces the loss of personnel and equipment. The recent conflict with Iraq clearly demonstrated the benefits of a superior intelligence capability and superior weapons and supporting systems, all used by highly trained professional men and women, from the soldier to the CINC. The advancement and protection of technology is a national security obligation.

1. Technology and National Military Strategy



2. The Cold War Defense Strategy

Strategic and Conventional Deterrence. Prior to the end of the cold war, our primary national security goals were to deter the Soviet Union from nuclear attack and to deter the Warsaw Pact from a massive conventional attack of Western Europe or other vital interests. These goals led to the strategic triad of nuclear-armed penetrating bombers, land-based ICBMs, and SSBNs, connected with a secure warning and control system and coordinated through a single integrated operating plan.

Conventional forces emphasized tactical nuclear forces, air superiority, air-land operations (heavy combat vehicles, fixed-wing aircraft, and helicopters), and carrier battle groups and attack submarines. Threats other than those posed by the Soviet Union and Warsaw Pact were recognized, and other missions were carried out. But as far as equipment, systems, and force structure were concerned, these threats were generally considered as "lesser included" cases.

Cold War S&T Drivers. The result was a DoD research and development system driven by:

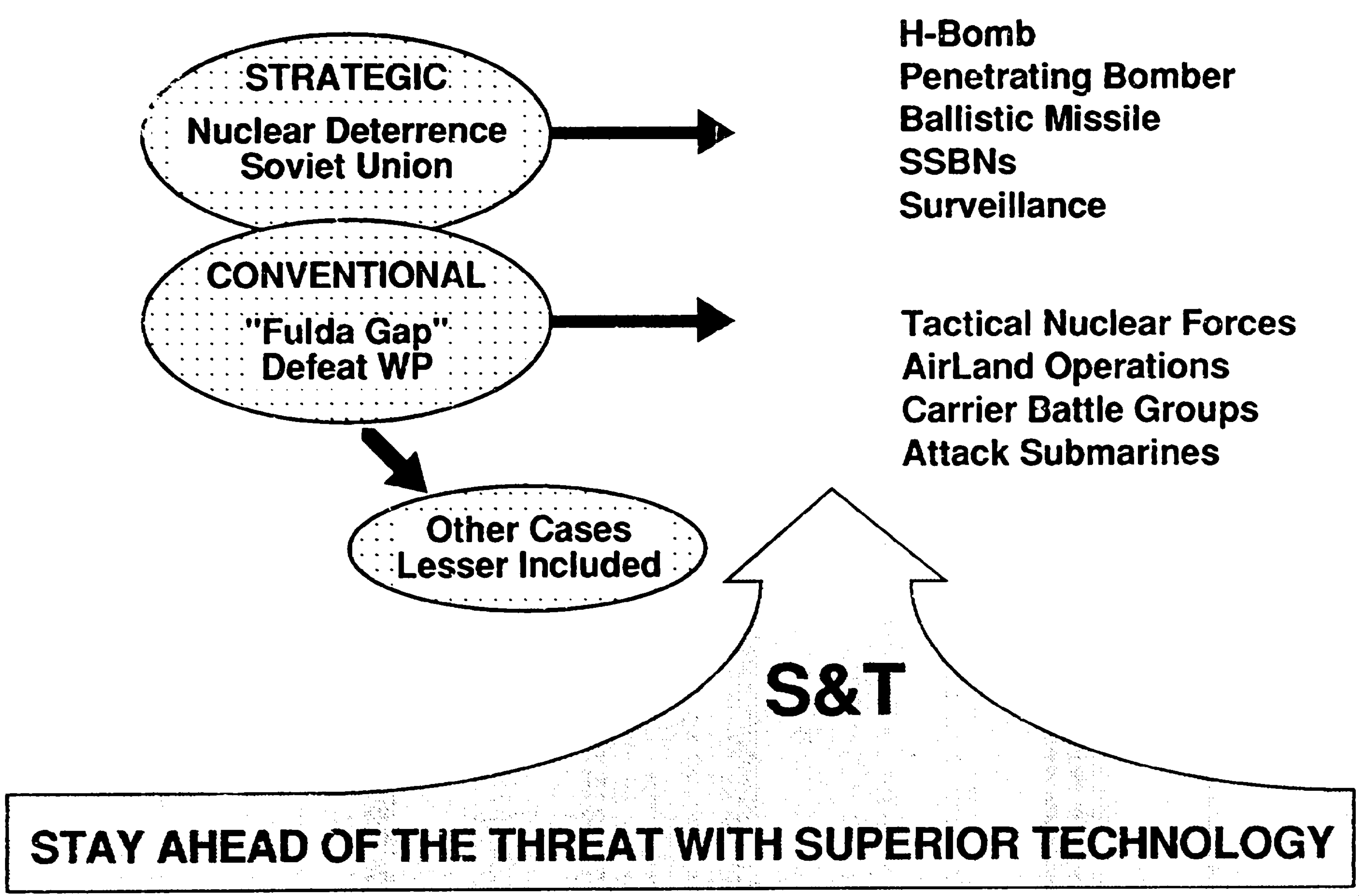
- The sense of urgency that comes from a threat to national survival.
- The anticipated intensity and scale of combat.
- The fact that the primary threat was comparable (if not equal) to us in both technology and readiness, and superior to us in numbers.
- The continuous investment of significant resources by the threat to improve its capabilities.

The first two drivers led, for example, to a willingness to accept the high economic costs associated with the necessary force structure. Greater emphasis was placed on maintaining military effectiveness over the course of a conflict, and less on minimizing casualties. These drivers also required us to invest heavily in science and technology, with a view toward staying ahead of the threat. The Soviet acquisition pipeline was about the same length as ours (up to 20 years), but ours led in most cases by five to ten years.

S&T Responsibilities. The investment in S&T covered a broad community: universities, government, and industrial laboratories and institutions, large and small, with a wide geographic distribution. Each military Service had its own S&T establishment, and other DoD agencies were created to meet specific national needs. The Defense Advanced Research Projects Agency (DARPA) was created to invest in "high risk/high payoff" technologies, and organizations like the Strategic Defense Initiative Organization (SDIO) arose to meet other specific requirements. Important investments in industry S&T have been financed primarily through the IR&D program.

S&T Success. Sometimes this process led to spectacular results (e.g., stealth), and sometimes technology did not live up to its expectations (e.g., directed energy weapons). On the whole, the acquisition strategy was successful. The Soviets were deterred, the cold war was won and, as Operation Desert Storm clearly demonstrated, U.S. military technology in the hands of skilled U.S. forces formed a superior and devastating combination. At the present time we have the best forces in the world.

2. The Cold War Defense Strategy



3. The New Defense Strategy

Fundamental Change in Threat and Strategy. Our previous defense and weapons acquisition strategies were driven by our competition with an adversary who possessed an ever-improving military juggernaut with a well-defined and active acquisition pipeline. The new defense and acquisition strategies are focused on a world filled with many potentially dangerous regional frictions.

The collapse of the Soviet Union means that in the foreseeable future we will not be involved in a large-scale struggle for national survival. Furthermore, there will be observable indications that will provide strategic warning of re-emerging threats capable of engaging in this class of conflict. The early recognition of such threats is the key to preventing surprises to decision makers.

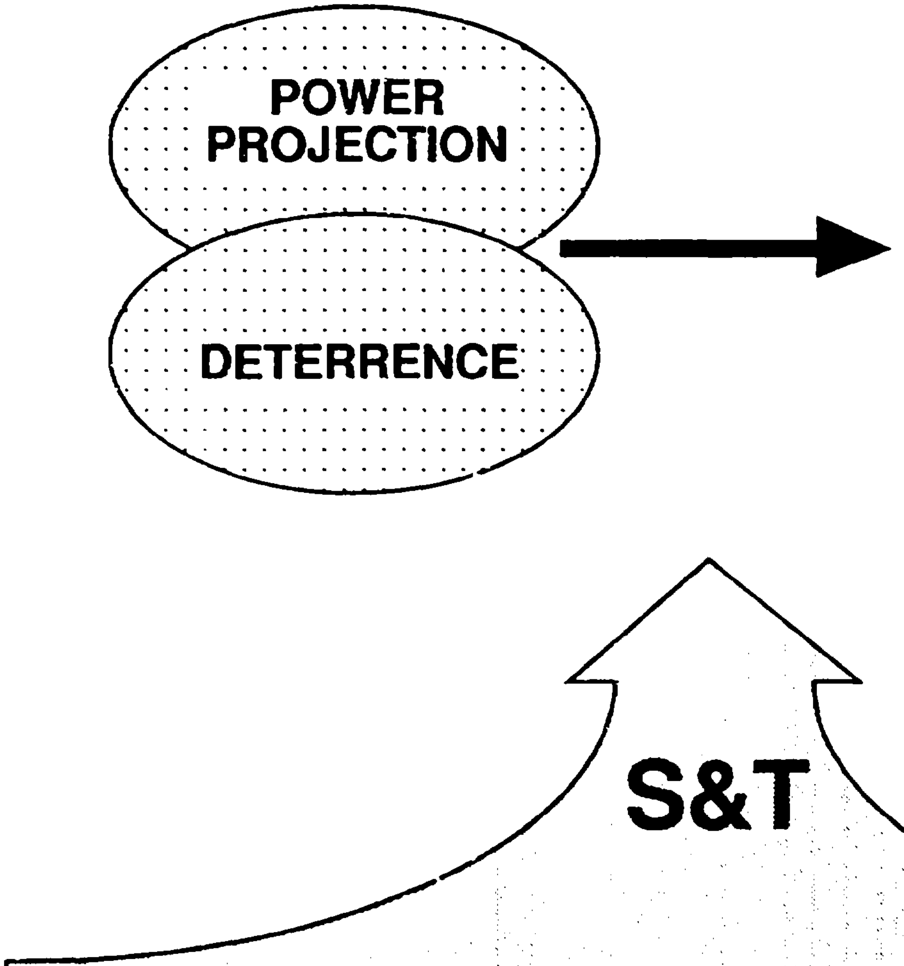
Although strategic deterrence remains a key foundation of our National Military Strategy, we must change our force structure to accommodate an increased emphasis on power projection and regional conflicts. The Base Force will be smaller, equipped with modern weapons, trained and ready, and supported by a vigorous research and development program. This will have to be accomplished, however, with a significantly reduced defense budget.

Implications of Regional Conflict. Regional conflicts inherently demand that a wide spectrum of options be made available to the National Command Authority. These options range from showing the flag to civilian evacuation, from surgical strikes to forcible entry and full-scale war. In addition to reduced support for large defense budgets, other constraints will affect our military strategy. Because there is no threat to the nation's survival and the scale of conflict is expected to be smaller, there will be a reduced tolerance for casualties in our forces and in the civilian populations of all parties. There will be diminished tolerance for protracted conflict.

The reduction in our forward basing posture increases the need to rapidly deploy forces, and to increase their fire power. The first forces to reach a conflict zone may need to defend themselves against a larger and heavier force until reenforcements arrive. They may also need to defend against weapons of mass destruction. The increased reliance on coalition warfare will require us to defend our partners and force the rapid resolution of conflicts.

The equipment we face will often be of Western quality, more technologically modern and militarily capable than the Soviet threat was. Even those regional powers without access to Western weaponry may possess high quality equipment from the former Soviet Union, providing them with a formidable fighting capability. Together with the significant reductions expected in the size of our force structure, these factors have profound implications for our S&T investment strategy.

3. The New Defense Strategy



Regional Conflicts

Limited Forward Basing

Minimal Casualties

Smaller Base Force

Coalition Warfare

Rapid Deployment

High Fire Power

Defense Against Weapons of Mass Destruction

SUPERIOR TECHNOLOGY TO DOMINATE POTENTIAL THREATS

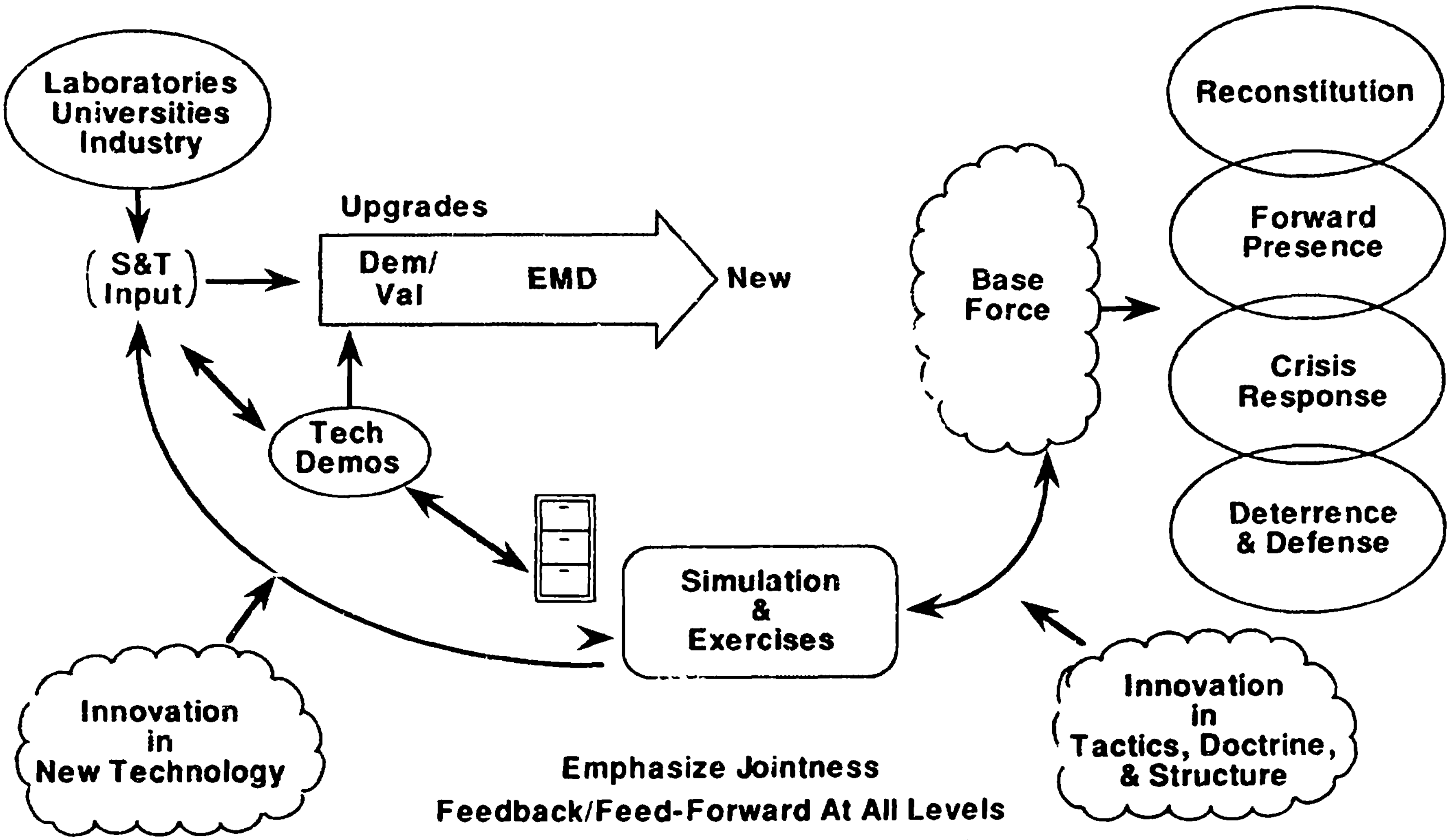
Technology Options. The new acquisition strategy accompanying the new defense strategy emphasizes the importance of the science and technology program. Specifically, it calls for continuously demonstrating technology in order to explore and provide technology options for force planners and other decision makers. Some technology demonstrations will lead to upgrades to current systems that can be readily absorbed within the current doctrinal and training framework. Others will lead to new capabilities that will be put into system development and production when the need is clear. Many demonstrations will become altogether new systems—going through the standard Demonstration/Validation (Dem/Val) and Engineering and Manufacturing Development (EMD) phases of the acquisition process. (The interface between the S&T program and the systems acquisition process is described in the 20 May 1992 DoD white paper on Defense Acquisition and Science and Technology Management Oversight.) This acquisition strategy has been carefully articulated by the Secretary of Defense:

> The end of the Soviet threat . . . [suggests] that we will be able to slow down our modernization efforts and still maintain our technological edge....This enables us to cancel some modernization efforts and to emphasize longer periods for research and development and for testing and proving the value of systems before buying. Accordingly, DoD has instituted a new acquisition strategy.
>
> The old U.S. acquisition strategy placed a premium on rapid development and procurement of new systems to counter rapidly evolving Soviet capabilities...Under the new U.S. acquisition strategy, there will be heavy emphasis on government-supported R&D to maintain the technology base. More work will be done with prototypes to demonstrate capabilities and prove out concepts. We plan to go to [production] on fewer systems, and only after having taken the time to prove out the concept. We will rely more often on inserting new capabilities into existing platforms and upgrades, instead of building totally new systems. We will also place greater emphasis on producibility of systems and manufacturing processes.

Simulation and User Involvement. The exercise and simulation of new technologies will allow the concurrent development of doctrine, tactics, and force structure. This also will ensure that operators are involved in the development of those technologies early in the game. These feedback and feed-forward loops will take place not just in conference rooms and training ranges, but also on simulated electronic battlefields. The ability to optimize the technologies prior to system development, and to allow an operational context to determine the employment and hence the scale of the production run, will lead to a more efficient allocation of resources. We will go forward to Dem/Val, EMD and production only when, as Secretary Cheney stated, "we have taken the time to prove out the concept."

Technological Superiority. Given as a starting point the world's best forces and systems, and an S&T strategy based on focused demonstrations and concurrent operational simulation and exercise, the United States can continue to expect an economical yet technologically superior force. In peace this force will deter. In crisis it will provide confidence to our allies, ensure the widest spectrum of options to our leadership, and make available key intelligence capabilities In war it will provide swift, economical, and decisive termination of conflict with minimal casualties.

3. The New Defense Strategy: *Acquisition*



Emphasize Jointness
Feedback/Feed-Forward At All Levels
Exploit Tech Revolution In Information
Support Reconstitution

1-9

4. The New S&T Strategy

The Core of the S&T Strategy. The S&T strategy will be tailored to deal with the new national security and acquisition realities, in particular the fact that our acquisition process no longer need be driven by the inexorable timetable of Soviet research, development, and acquisition. The core of this strategy is to (1) provide for the early, intensive, and continued involvement of warfighters, (2) fuel and exploit the explosion in information technologies, and (3) conduct extensive and realistic technology demonstrations.

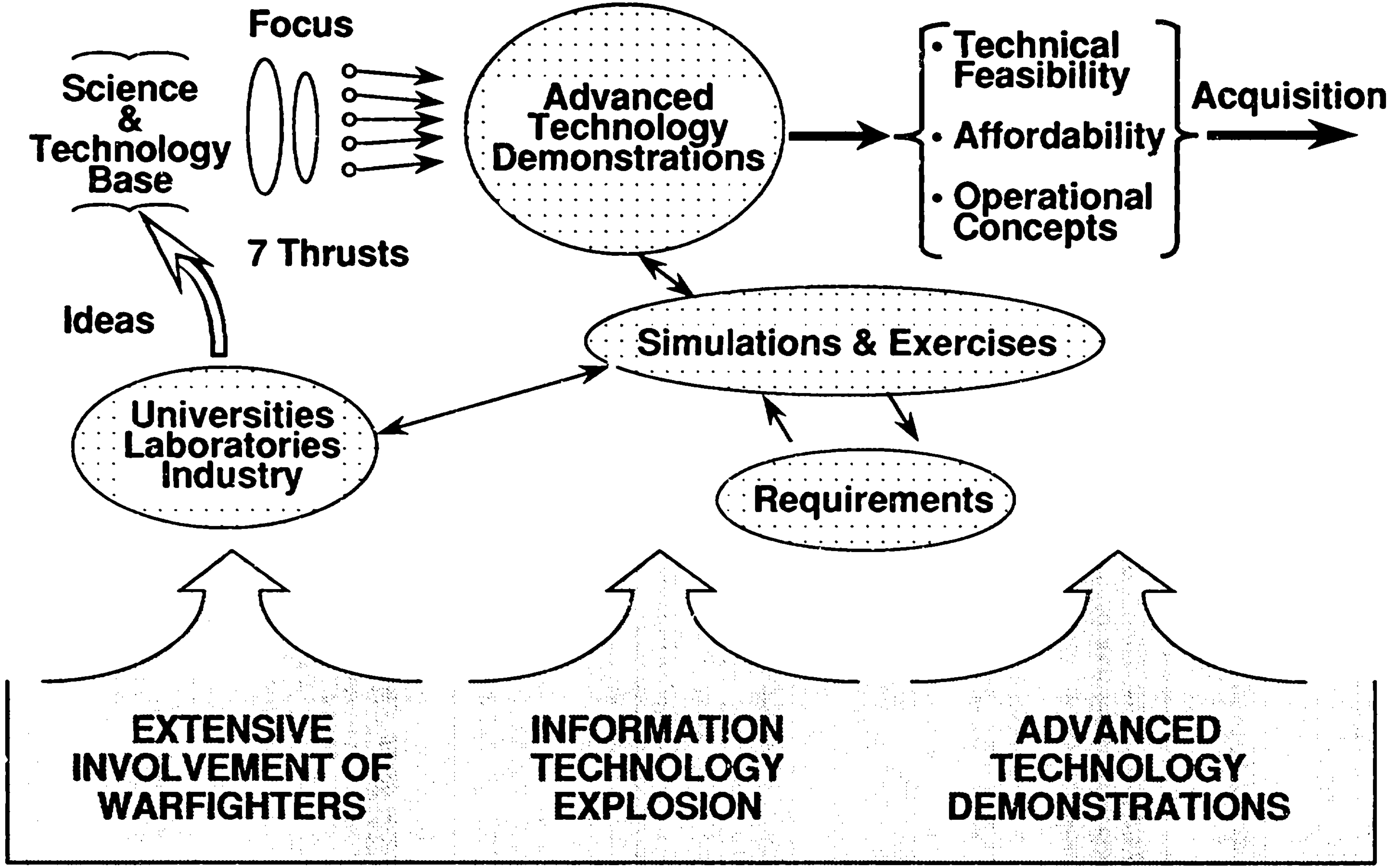
The S&T strategy seeks to promote and take advantage of the information technology explosion and to adapt and convert it into military technologies that could revolutionize military operations. The growth in the density, speed, and types of integrated circuits has been remarkable and has fueled the exponential increase in the performance of modern computers.

These advances, together with the development of increasingly capable computer networks, create unprecedented opportunities. We will be able to design and build better and more affordable systems; train our personnel to achieve higher levels of mastery and professionalism; and create a more effective command, control, communications, and intelligence (C3I) structure.

This information technology explosion will, for example, make it possible to create distributed simulation exercises that involve the operator (the user, or "warfighter") directly and intimately in the evaluation of Science and Technology programs. Advanced Technology Demonstrations (ATDs) will be employed to ensure that technologies are ready, that manufacturing processes are in place, and that the operational concepts for their use are understood and validated before proceeding to the next phase of the acquisition process.

The following pages describe how we intend to increase user involvement in the S&T process, the significance of the information technology explosion, and the role that is to be played by ATDs. Also described are the roles of the research and exploratory development programs (budget categories 6.1 and 6.2) and the management systems that are being put into place to tie them together and ensure that they enhance the ATD program.

4. The New S&T Strategy



4. The New S&T Strategy: *Involvement of Warfighters*

An essential innovation in the execution of the S&T strategy is the continuous and intensive involvement of users—warfighters—in the process that designs, produces, tests, and delivers systems.

The current requirements process begins with the users, who document a military need in a comprehensive format that is then provided to developers. The user then steps back while candidate systems are designed, prototyped, and tested to see if they meet the requirement. This process helps clarify roles and responsibilities, but can also restrict communication and make tradeoff analyses difficult.

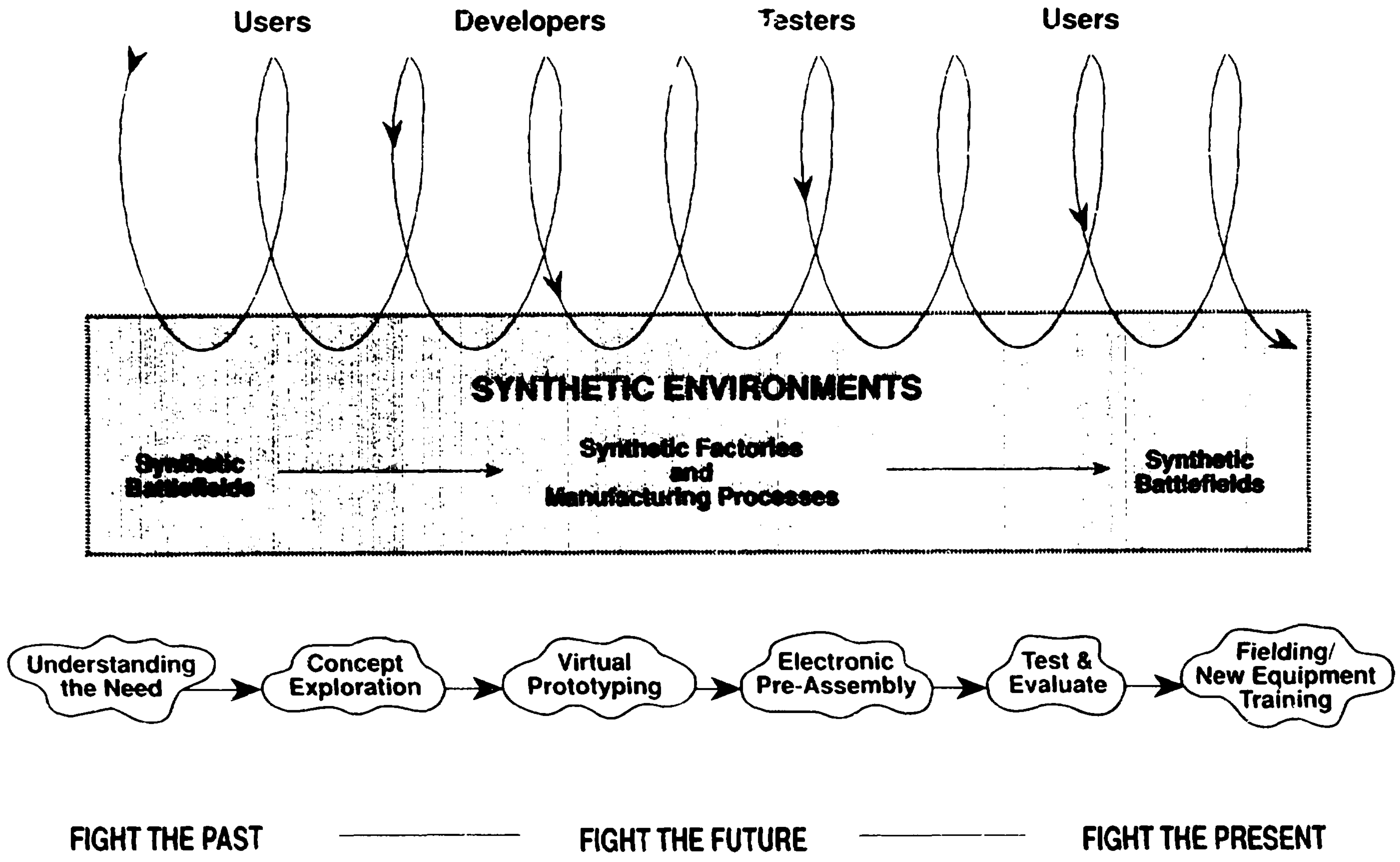
Synthetic Environments. Breakthroughs in advanced simulation technology promise dramatic improvements in this process. A new generation of distributed, seamless simulations can create realistic "synthetic" battlefields and permit simultaneous entry onto these battlefields from numerous locations. Military planners, operators, commanders, and their forces can use these battlefields to better understand the complexities of future power projection roles and missions. They then can communicate these needs in an operational context more clearly and vividly to the development community, which is also "on the net." As candidate solutions are proposed across the community, they can be tried out synthetically and shown to all concerned. The processes of requirements definition, specification, design, prototyping, testing, and fielding will be more integrated and effective.

Synthetic environments are being networked throughout the scientific and development communities to bring warfighters, developers, scientists, engineers, testers, and manufacturers together. They will continue to become more seamless; that is, entry onto the synthetic battlefields could be from netted simulators, workstations, instrumented real combat vehicles on ranges, or detailed object-oriented models and algorithms. Synthetic battlefields will be able to link forces in a theater of operations to exercises based in the United States.

These environments are also spreading into the manufacturing sector, with the same root technologies allowing the construction of synthetic factory floors, material delivery systems, and product distribution and use systems. When delivered to synthetic battlefields for use by operators engaged in force-on-force combat, usage and costs are better documented and the implications for the total force can be better evaluated.

Feedback and Feed-Forward. Synthetic environment capabilities will allow the S&T strategy to benefit from the feedback of concepts and doctrine from the operators to the developers of technology and systems, and the "feed-forward" of new technology and systems from the developers to the operators. The strategy is one of continuous iteration and teamwork to better understand what is needed for the future and to develop cooperative solutions.

4. The New S&T Strategy: *Involvement of Warfighters*



4. The New S&T Strategy: *Information Technology Explosion*

The information technology explosion is transforming our ability to collect, understand, disseminate, and apply information on a global scale. Harnessing this explosion is central to the entire Science and Technology Strategy.

Numbers, Performance, and Networks. The transistor was invented in 1948 as a replacement for the vacuum tube; it was the basis for the invention of the integrated circuit—the chip—a little over a decade later. The growth of the transistor-based integrated circuit industry is unmatched in this century. By 1993 we can expect 10 million transistors to be produced for every man, woman, and child on earth, and most of these transistors will be in the form of chips. By the end of the 1990s we can expect to have chips containing a billion transistors.

Chips are the main building blocks of modern computers, whose performance is increasing exponentially. Using massive parallel architectures, supercomputers in the teraop range—that is, one trillion operations per second—will be operational in a few years.

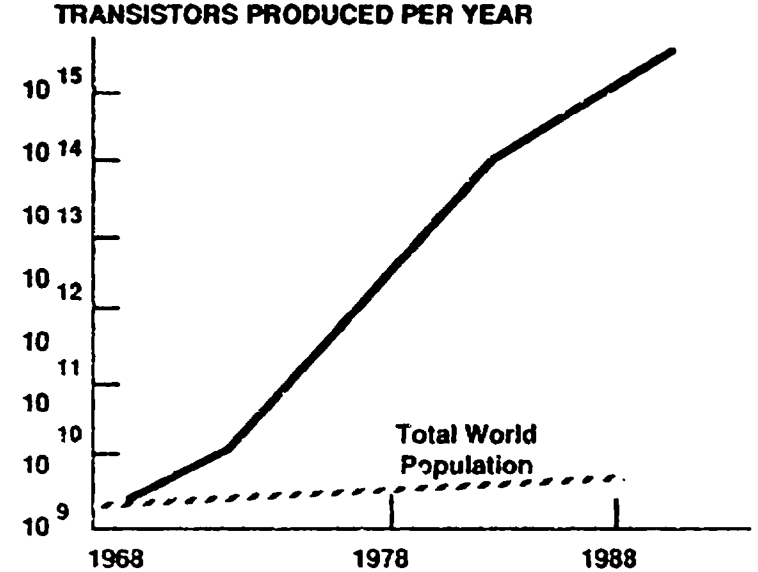
But the story does not end with stand-alone computers. Computer networking started in 1969 when DARPA (then ARPA) hooked four computers together. That experiment grew to be ARPANET, which expanded to become MILNET, which has become part of the INTERNET. The number of computers on the INTERNET is expected to reach 10 million by 1996, and transmission rates have increased by a factor of 20,000.

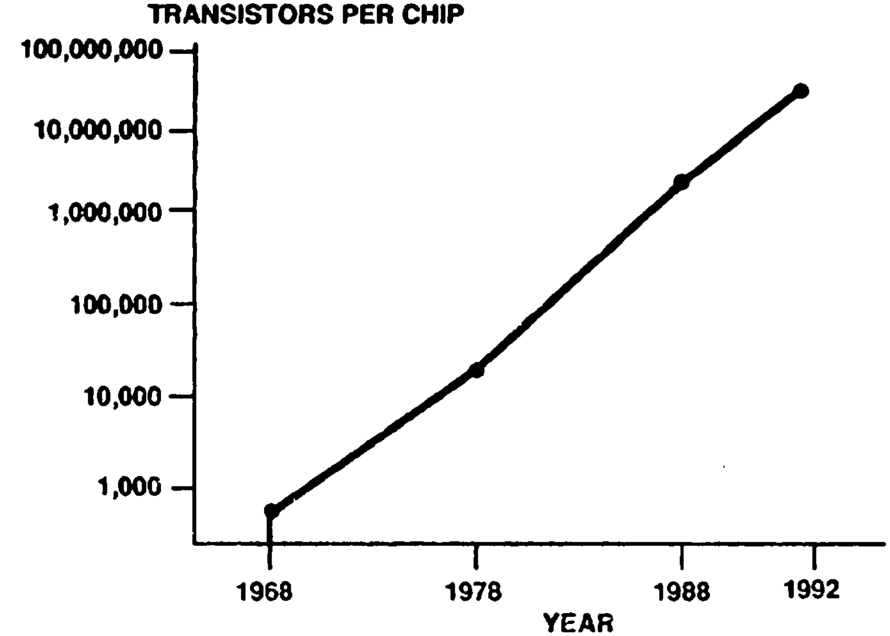
Interlocking Technologies. What is striking about these numbers is not simply their magnitude and continued growth, but the interlocking nature of the technologies that underlie this growth.

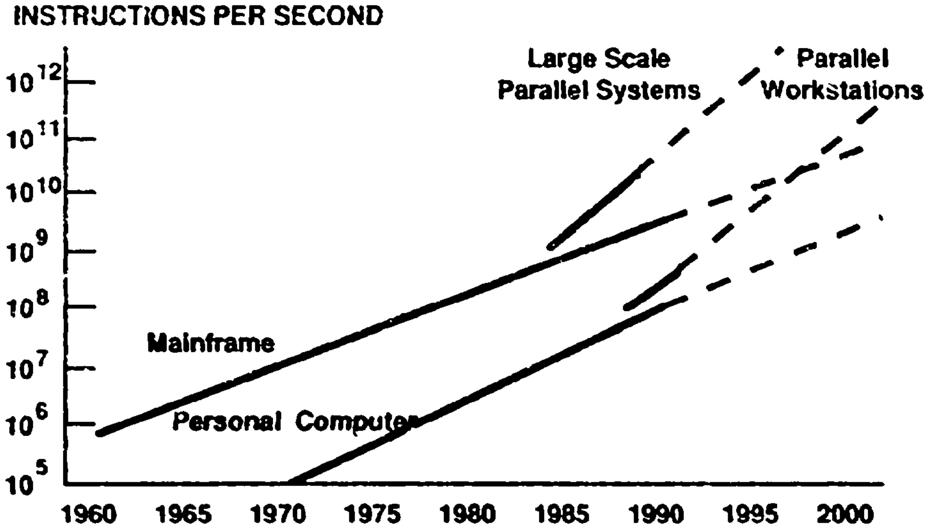
Advanced chips, including the technologies required to package and interconnect them, are the foundation of computers, and computers (and their software) enable the design and building of the next generation of advanced chips, which are used to design, build, and operate the factories that create chips and computers. The switches for computer networks are themselves computers, and computer-aided design, manufacturing, logistics, and management systems are really information networks. So, too, are the command, control, communications, and information (C3I) systems that are the sensors, brains, and nervous system of modern military operations.

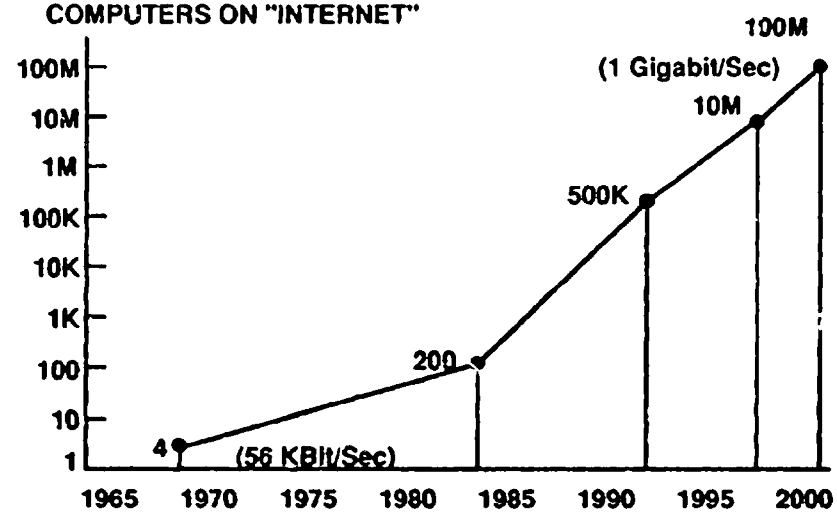
Indeed, one could characterize the entire information technology revolution and its application to national security as the creation, maintenance, and operation of an ever-expanding, adaptive network of systems and networks. These range from precision-guided weapons to the factories and design teams that build them. Because they are both ubiquitous and powerful, these information technologies and their applications to other technologies and systems have become paramount to the Department of Defense.

4. The New S&T Strategy: *Information Technology Explosion*









4. The New S&T Strategy: *Advanced Technology Demonstrations*

S&T in the Revised Acquisition Strategy. The ultimate goal of the S&T strategy is to provide new or improved capabilities to the operating forces. Accordingly, the strategy must be coupled to the DoD acquisition system to effect the successful transition of technology. A primary objective of the new acquisition approach is to conduct more rigorous "up-front" technology developments so that the formal acquisition cycle can be made less risky. Technologies will remain in the S&T program until they are fully matured and ready for application to upgrades of existing systems or to a new system. Maintaining the technological advantage enjoyed by U.S. forces will continue to be a high priority of the revised acquisition system.

The Role of ATDs. A vital component of both the S&T strategy and the acquisition strategy is the initiation of specific technology demonstrations to lay the foundation for acquiring new or improved warfighting capabilities. These demonstrations, termed Advanced Technology Demonstrations (ATDs), will range from demonstrating the military utility of new technological concepts in a laboratory environment to integrating and assessing technology in as realistic an operational environment as possible. ATDs are designed primarily as programs which have the promise of making a significant impact on future military capabilities.

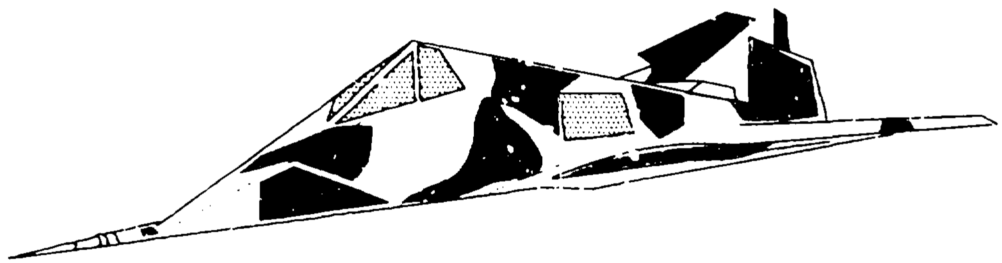
There are generally two types of ATDs—those focused on new system and subsystem concepts, and those focused on "enabling" technologies. These demonstrations of capability, coupled with advanced simulation techniques, will lead to comprehensive assessments of technical feasibility, affordability, and operational utility.

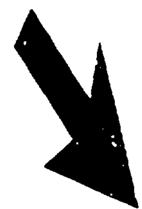
Technology demonstrations are nothing new. The Have Blue aircraft demonstrated that stealth was feasible in a flying aircraft prior to the development of the F-117. Assault Breaker demonstrated the radar technology for the Joint Surveillance and Target Acquisition Radar System (JSTARS) and the Advanced Tactical Missile (ATACM) system. The Millimeterwave and Microwave Monolithic Integrated Circuits (MIMIC) program has demonstrated the ability to produce low-cost integrated circuits.

What is new is the scope and depth of the technology demonstrations and their central role in the acquisition process. Significantly more emphasis is being placed on demonstrating potential improvements to important military capabilities. Every Advanced Technology Demonstration will be designed to assess for acquisition managers the extent to which the technology is feasible, affordable, and compatible with operational concepts and projected force structure. The discussions of each of the S&T Thrusts in Section II contain details of the current and planned ATD program for each Thrust. These range from small satellites to weapons for precision strike to information-intensive manufacturing systems for infrared focal plane arrays. These ATDs will be the focus of the funding in the advanced development program (budget category 6.3A).

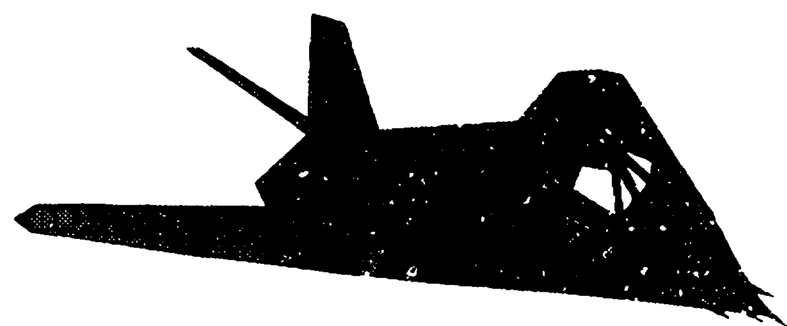
4. New S&T Strategy: *Advanced Technology Demonstrations*

HAVE BLUE





F-117



- Demonstrate Technology More Rigorously "Up-Front"
- Fully Mature Technologies in S&T Before Going to New or Upgraded System
- Demonstrate Technical Feasibility, Affordability, and Operational Utility
- Make a Significant Difference in Future Military Capability

4. The New S&T Strategy: *The Seven S&T Thrusts*

Focus In The S&T Program. The S&T program is focused on seven broad areas of capability. These areas emphasize the need to minimize casualties, accommodate to a smaller force structure, improve joint operations, and retain the technological edge against all potential threats. While there are other goals and activities that fall outside of these Thrusts, it is important to focus the program on those efforts which are most important, rather than simply provide a "balance" across all possible investment options. Focus, not balance, is the watchword of the new S&T strategy.

The seven Thrusts represent our current assessment of the demands being placed on the S&T program by the users' most pressing military and operational requirements. As national security requirements, operational needs, and technology evolve, additional thrusts could be added and existing thrusts might change. The planning process is a flexible one. Section II of this strategy provides a more detailed look at each of the Thrusts.

1. Global Surveillance and Communications. The ability to project power requires a global surveillance and communications capability that can focus on a trouble spot, surge in capacity when needed, and respond to the needs of the commander.

2. Precision Strike. The desire for reduced casualties, economy of force, and fewer weapons platforms demands that we locate high-value, time-sensitive fixed and mobile targets and destroy them with a high degree of confidence within tactically useful timelines.

3. Air Superiority and Defense. The need to defend deployed military forces, and help defend allies and coalition partners, from the growing threat of high performance aircraft and ballistic and cruise missiles, and the need to maintain decisive capabilities in air combat, interdiction, and close air support, require a strong effort in missile defense and air superiority.

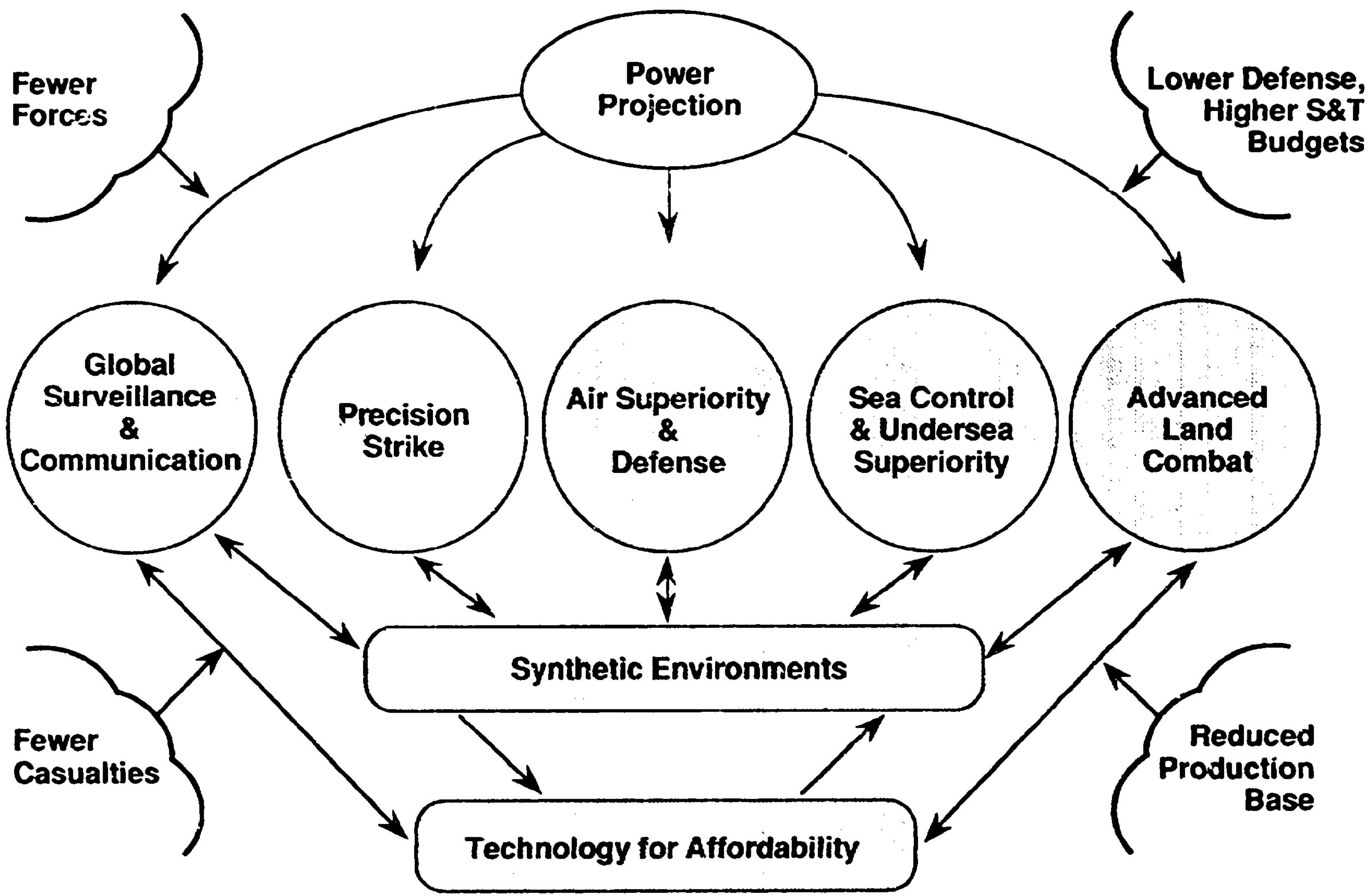
4. Sea Control and Undersea Superiority. The ability to maintain overseas presence, conduct forcible entry and naval interdiction operations, and operate in littoral zones, while keeping loses to a minimum, presupposes a strong capability in sea control and undersea warfare.

5. Advanced Land Combat. The ability to rapidly deploy our ground forces to a region, exercise a high degree of tactical mobility, and overwhelm the enemy quickly and with minimal casualties in the presence of a heavy armored threat and smart weaponry requires highly capable land combat systems.

6. Synthetic Environments. A broad range of information and human interaction technologies must be developed to synthesize present and future battlefields. We must therefore synthesize factory-to-battlefield environments with a mix of real and simulated objects and make them accessible from widely dispersed locations. Integrated teams of users, developers, and/or testers will be able to interact effectively. Synthetic environments will prepare our leaders and forces for war and will go with them to the real battlefield.

7. Technology for Affordability. Technologies that reduce unit and life cycle costs are essential to achieving significant performance and affordability improvements. Manufacturing process and product performance issues are integral parts of the program. Advances are particularly needed in technologies to support integrated product and process design, flexible manufacturing systems that decouple cost from volume, enterprise-wide information systems that improve program control and reduce overhead costs, and integrated software engineering environments.

4. The New S&T Strategy: *The Seven S&T Thrusts*



5. Science and Technology Management: *Research (6.1)*

The remainder of Section I describes how the S&T program will be managed to implement the strategy. Of critical importance are the roles to be played by DDR&E and the Services and Agencies in the interactions between the research program (budget category 6.1), the Key Technology Areas (6.2—exploratory development), and the seven Thrusts (6.3A—advanced development and the ATDs). Details on the 6.1 and 6.2 programs are given below. Section II provides details of the 6.3A program through a look at each of the Thrusts. A more detailed treatment of the S&T management processes being implemented by the DDR&E is contained in other documents.

Research (6.1)

The Department of Defense conducts an aggressive program of research (budget category 6.1) to create or exploit unforeseen scientific breakthroughs and to create or guard against technological surprise. It also ensures that both cutting-edge scientific discoveries and the general store of scientific knowledge are optimally utilized in the development of superior military equipment, strategies, and tactics. While all research focuses on essential science, a sustaining program outside the specific S&T Thrusts (budget category 6.3A) is essential. Through this activity the DoD strives to achieve a number of goals:

- To foster the discovery of new phenomena in those aspects of the mathematical, physical, engineering, environmental, and life sciences offering high potential for defense utilization, and develop the deeper understanding necessary for their military application.
- To gain clear visibility into the worldwide reservoir of scientific knowledge and rapidly exploit scientific advances wherever they may originate.
- To facilitate the transition of research results to further stages of the defense development cycle.
- To strengthen the research infrastructure in defense laboratories, and in the academic and non-profit laboratories which serve the DoD, including fostering the training of scientists and engineers in disciplines critical to defense needs.
- To facilitate the spin-off, where appropriate, of defense research results to the civil and commercial sectors.

As a consequence of its long time horizon, the process of realizing the ultimate revolutionary and evolutionary payoffs of research requires long-term nurture, commitment, and funding stability. At the same time, it is recognized that some near-term advances do inevitably emerge, and mechanisms are in place to speed their application.

At an annual funding level of approximately $1 billion, DoD basic research accounts for eight percent of total federal funding and five percent of total national funding for basic research (federal, state, and private). Thus, DoD is a significant, but not dominant, component of overall U.S. funding for basic research. Consequently, DoD focuses on selected areas of critical importance that are not adequately addressed elsewhere. It is a major source of basic research support in electrical engineering, materials science, applied mathematics, and computer science, all of which are of particular importance to DoD.

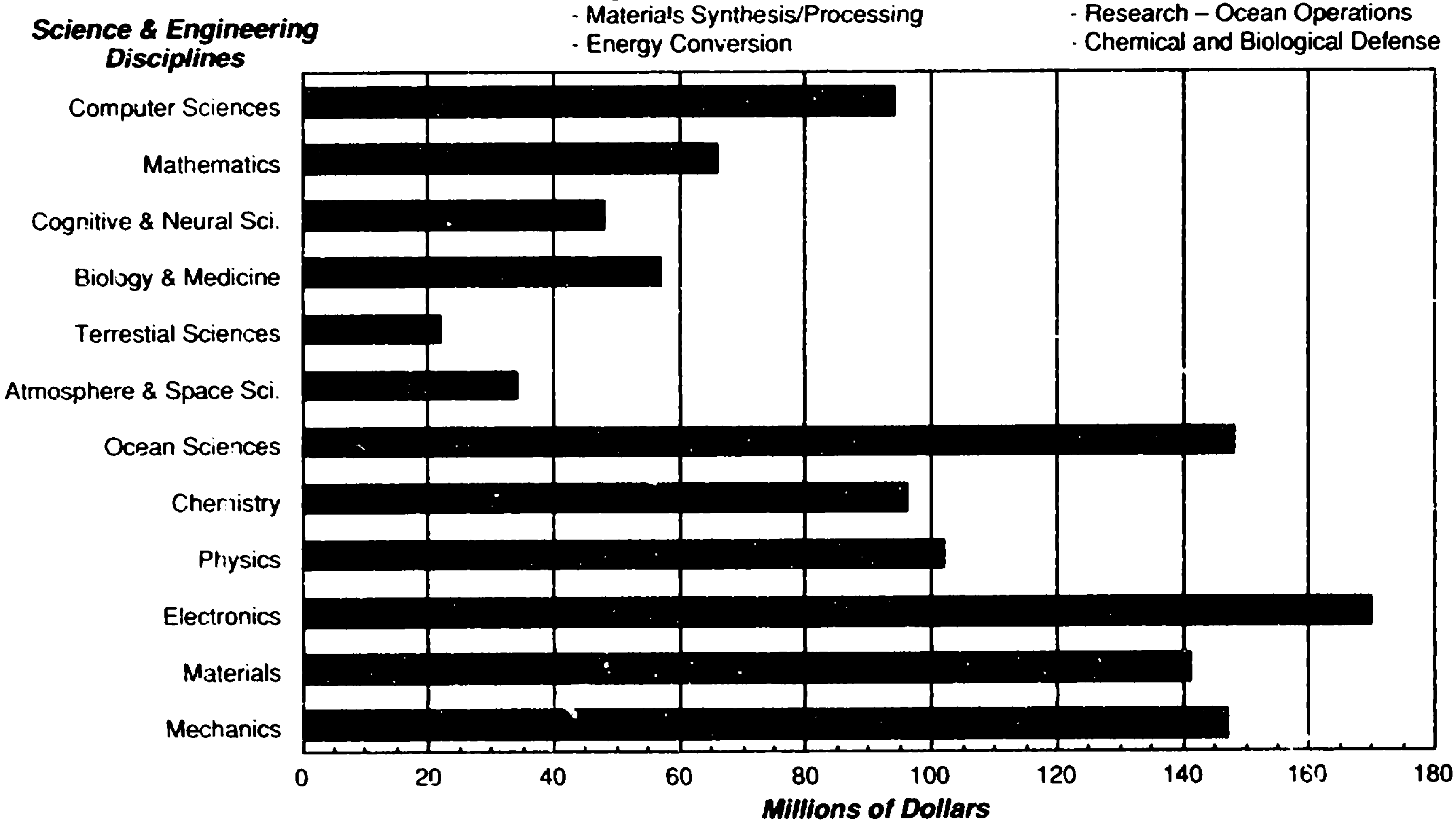
The research program supports work in 12 science and engineering disciplines, as shown in the accompanying figure. Once again, funding is focused on those areas with a high long-term potential for providing important contributions to the Key Technology Areas and other defense applications.

5. Science & Technology Management: *Research 6.1*

Projected FY 1993 6.1 Funding

Representative Research Directions

- Information Processing
- Electronics/Optoelectronics
- High Performance Computing
- Materials Synthesis/Processing
- Energy Conversion
- Active Control-Aerospace Vehicles, Weapons
- Research – Rotorcraft
- Research – Ocean Operations
- Chemical and Biological Defense



5. Science and Technology Management: *Key Technology Areas (6.2)*

Exploratory Development. The exploratory development program (budget category 6.2) focuses on the maturation of technologies before they are considered for transition to ATDs. This process involves proof of concept experiments and evaluations supported by models and simulation. The program is built around 11 "Key Technology Areas," the technologies determined to have the highest relative importance to future military needs. The primary goal of the DDR&E's management guidance and oversight efforts is to ensure that the S&T program is structured to support the goals established for each of the seven Thrusts. The accompanying table shows, for each Thrust, the one Key Technology Area having the highest priority, the two in which a priority effort is required, and those that are very important.

1. **Computers.** High performance computing systems (and their software operating systems) providing orders-of-magnitude improvements in computational and communications capabilities as a result of improvements in hardware, architectural designs, networking, and computational methods.

2. **Software.** The tools and techniques that facilitate the timely generation, maintenance, and enhancement of affordable and reliable applications software, including software for distributed systems, database software, artificial intelligence, and neural nets.

3. **Sensors.** Active sensors (with emitters, such as radar and sonar), passive ("silent") sensors (e.g., thermal imagers, low light level TV, and infrared search and track systems), and the associated signal and image processing.

4. **Communications Networking.** The timely, reliable, and secure production and worldwide dissemination of information, using shared communications media and common hardware and applications software from originators to DoD consumers, in support of joint-Service mission planning, simulation, rehearsal, and execution.

5. **Electronic Devices.** Ultra-small (nano-scale) electronic and optoelectronic devices, combined with electronic packaging and photonics, for high speed computers, data storage modules, communication systems, advanced sensors, signal processing, radar, imaging systems, and automatic control.

6. **Environmental Effects.** The study, modeling, and simulation of atmospheric, oceanic, terrestrial, and space environmental effects, both natural and man-made, including the interaction of a weapon system with its operating medium and man-produced phenomena, such as obscurants found on the battlefield.

7. **Materials and Processes.** Development of man-made materials (e.g., composites, electronic and photonic materials, smart materials) for improved structures, higher temperature engines, signature reduction, and electronics, and the synthesis and processing required for their application.

8. **Energy Storage.** The safe, compact storage of electrical or chemical energy, including energetic materials for military systems.

9. **Propulsion and Energy Conversion.** The efficient conversion of stored energy into usable forms, as in fuel efficient aircraft turbine engines, and hypersonic systems.

10. **Design Automation.** Computer-aided design, concurrent engineering, simulation, and modeling, including the computational aspects of fluid dynamics, electromagnetics, advanced structures, structural dynamics, and other automated design processes.

11. **Human-System Interfaces.** The machine integration and interpretation of data and its presentation in a form convenient to the human operator; displays; human intelligence emulated in computational devices; and simulation and synthetic environments.

5. S&T Management: *Key Technology Areas (6.2)*

Key Technology Area / Thrust	(1) Computers	(2) Software	(3) Sensors	(4) Communications Networking	(5) Electronic Devices	(6) Environmental Effects	(7) Materials and Processes	(8) Energy Storage	(9) Propulsion and Energy Conversion	(10) Design Automation	(11) Human-System Interfaces
(1) Global Surveillance & Communications	○	○	●	*	●	○	○	○	○	○	○
(2) Precision Strike	○	*	●	●	○	○	○	○	○	○	○
(3) Air Superiority and Defense	●	○	*	○	●	○	○	○	○	○	○
(4) Sea Control and Undersea Superiority	●	○	*	○	○	○	○	○	○	●	○
(5) Advanced Land Combat	○	○	●	●	○	○	*	○	○	○	○
(6) Synthetic Environments	○	○	○	○	○	○				●	*
(7) Technology for Affordability	○	●		○	○		●			*	○

* Highest Priority (1) ● Priority Effort (2) ○ Very Important

5. Science and Technology Management: *Matrix Management*

The three crucial elements to the successful implementation of the S&T strategy—the seven Thrusts, the Key Technology Areas, and the Service and Agency programs—are represented in the "Technology Management Cube." This illustrates the nature of the matrix management being applied to the S&T program.

Seven Thrusts. Each Thrust has a leader who reports directly to the DDR&E. The Thrust Leaders' responsibilities are to oversee and coordinate the Service and Agency programs which bear on each Thrust, with the primary emphasis on Advanced Technology Demonstrations (ATDs) in the advanced development (budget category 6.3A) program. The actual execution of the program is left to the line managers in the Services and Agencies. Within each Thrust, specific ATDs are being identified that are required to meet the goals established for that Thrust, and detailed roadmaps to guide their progress are being developed.

As illustrated in the Technology Management Cube by the plane marked at the corners with a "T," the Thrust Leader must, in one direction, be concerned with the developments taking place in all of the Key Technology Areas; in the other direction, the Thrust Leader must ensure that the ATDs being pursued by the Services and Agencies are consistent with the goals of the Thrust.

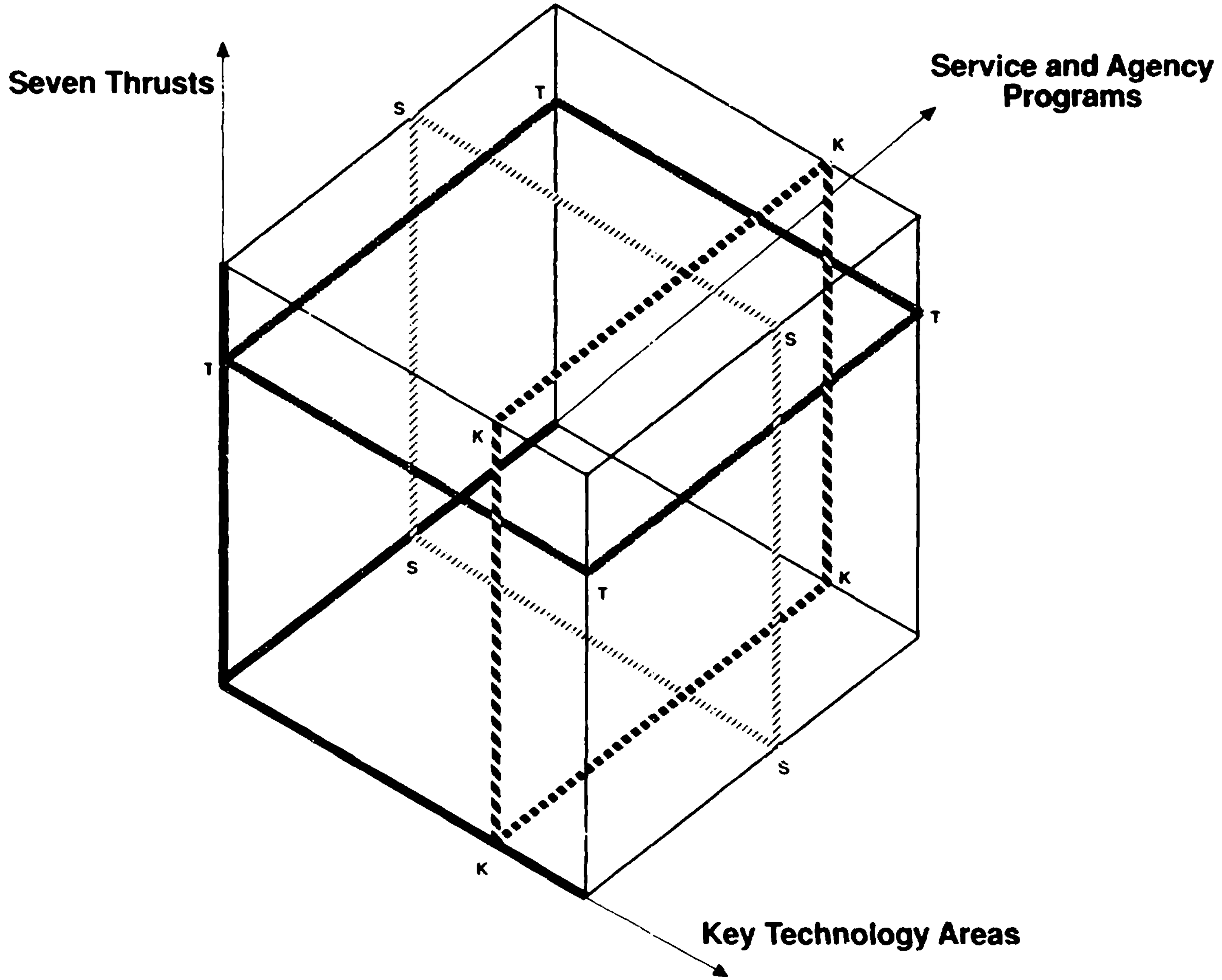
Key Technology Areas. Each of the 11 Key Technology Areas has been assigned to a Senior Technologist who reports to the Deputy Director of Defense Research and Engineering (Science and Technology). Their responsibilities are to ensure that the technologies required by the Thrust ATDs are being properly pursued within the Service and Agency programs and support the goals of the Thrusts. Within the DDR&E organization, therefore, is a matrix organization in which the Thrusts (Thrust Leaders) are supported by the Key Technology Areas (Senior Technologists). The plane marked at the corners with a "K" indicates this set of responsibilities, as does the matrix on page I-23.

Service and Agency Programs. The third axis on the Technology Management Cube represents the separate programs executed by the individual Services and Agencies. The plane marked at the corners with an "S" indicates that these programs must support the goals of the seven Thrusts, both directly and through their support of the 11 Key Technology Areas. The coordination between their programs and the Key Technology Areas will take place through the Project Reliance structure (for the Services, see pages I-26 and I-27), whenever that is available.

Meeting Military Needs. The success of the seven Thrusts depends on the availability and integration of advanced technology to meet military needs. Consequently, the management philosophy underlying the S&T strategy emphasizes meeting the needs of the customer—"requirements pull"—while at the same time making available to the customer new technologies to meet pressing operational problems—"technology push." The management structure outlined here shows how the DDR&E intends to coordinate the management interactions of all elements of the S&T program.

Oversight and Guidance of 6.3A. The DDR&E leads the planning of all S&T activities and has decision authority on the allocation of funds to each element of the S&T program. The remainder of this document provides details of the guidance being provided to the Services and Agencies for their Advanced Technology Demonstration (ATD) programs in each of the seven Thrusts.

5. S&T Management: *Matrix Management*



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5. Science and Technology Management: *Project Reliance and the Key Technology Areas*

Project Reliance is a tri-Service, Joint Directors of Laboratories (JDL) effort initiated by the Services to improve the coordination among, and thereby the efficiency of, the Service science and technology programs, laboratories, and research centers. This effort entails reducing unwarranted duplication of effort among the laboratories of different Services, combining some efforts so that there is sufficient "critical mass" to ensure an efficient research program, and planning and executing joint programs. A similar approach built around Science Planning Groups has been implemented to ensure a coordinated and efficient basic research program.

There are 16 Reliance Panels that are used for joint planning: Advanced Materials, Air Vehicles, Sensors, Electronic Device, Computer Science, Electronic Warfare, Command, Control, and Communications, Space Vehicles, Environmental Sciences, Conventional Air/Surface Weaponry, Directed Energy Weapons, Manpower and Personnel, Training Systems, Environmental Quality, Civil Engineering, and Medical.

There are, in addition, several other technology areas for which there are no Reliance Technology Panels. Oversight for the following areas is provided by the Joint Directors of Laboratories Management Panel: robotics; ships and watercraft; fuels and lubes; clothing, textiles, and food; ground vehicles; nuclear weapons effects; astrometry; and chemical and biological defense.

A comparison of these technology areas and panels with the 11 Key Technology Areas will show that many of the Reliance technologies are more applications-oriented than are the Key Technology Areas, which are broader and more generic in scope. One important reason for this difference is that the Reliance effort was specifically designed to increase each Service's adoption of technologies available from the other Services. Moreover, Reliance captures the full scope of the Services' 6.2 and 6.3A programs (except those that are Service-unique), while the DDR&E Key Technology Areas are designed to capture the 6.2 program, and the seven Thrusts capture the 6.3A program.

The DDR&E management interactions with the Services and Reliance will be conducted in the following way: Each of the 11 Key Technology Areas is being assigned to a Senior Technologist on the DDR&E (S&T) staff. The Senior Technologist will have the responsibility for working with the appropriate Reliance panels—and with the appropriate personnel from the Defense Agencies—to ensure the development of technologies required to support the seven Thrusts. The table on the facing page shows some of the relationships between these two organizational arrangements.

5. S&T Management: *Reliance & Key Technology Areas*

Reliance Panel \ Key Technology Area	(1) Computers	(2) Software	(3) Sensors	(4) Communi-cations Networking	(5) Electronic Devices	(6) Environ-mental Effects	(7) Materials and Processes	(8) Energy Storage	(9) Propulsion and Energy Conversion	(10) Design Automation	(11) Human-System Interfaces
1. Advanced Materials							X				
2. Air Vehicles							X		X	X	X
3. Sensors			X				X				
4. Electronic Devices					X		X				
5. Computer Sciences	X	X									
6. Electronic Warfare	X	X	X	X							X
7. C3	X	X	X	X							X
8. Space Vehicles							X	X	X		X
9. Environmental Sciences						X					
10. Conventional Air/ Surface Weapons								X	X		
11. Directed Energy Weapons	X	X		X				X	X		
12. Manpower & Personnel											X
13. Training Systems			X							X	X
14. Environmental Quality											
15. Civil Engineering										X	
16. Medical											
17. JDL Management Panel	X	X	X	X	X	X	X	X	X	X	X

*Only major correspondences are indicated.

II. THE SEVEN S&T THRUSTS

The Seven Thrusts

The remainder of this document provides details on the guidance being provided by the DDR&E to the Services and Agencies with respect to the seven S&T Thrusts. This top-level guidance for each Thrust is presented in four pieces: Legacy, Functions and Goals, Top-Level Demonstrations, and Key Technology Areas.

Legacy. The Legacy chart, and accompanying text, outline the gains in military capability expected from the science and technology program. Tomorrow's achievements will be the legacy of today's S&T investments.

Functions and Goals. The next chart and text outline the specific (military) functions served by each Thrust, and provide more details on the long-term goals for improving the military capability for each function.

Top-Level Demonstrations. The next chart is a "Technology Roadmap," which provides examples of how the goals established for each Thrust are to be accomplished through investments in Advanced Technology Demonstrations (ATDs).

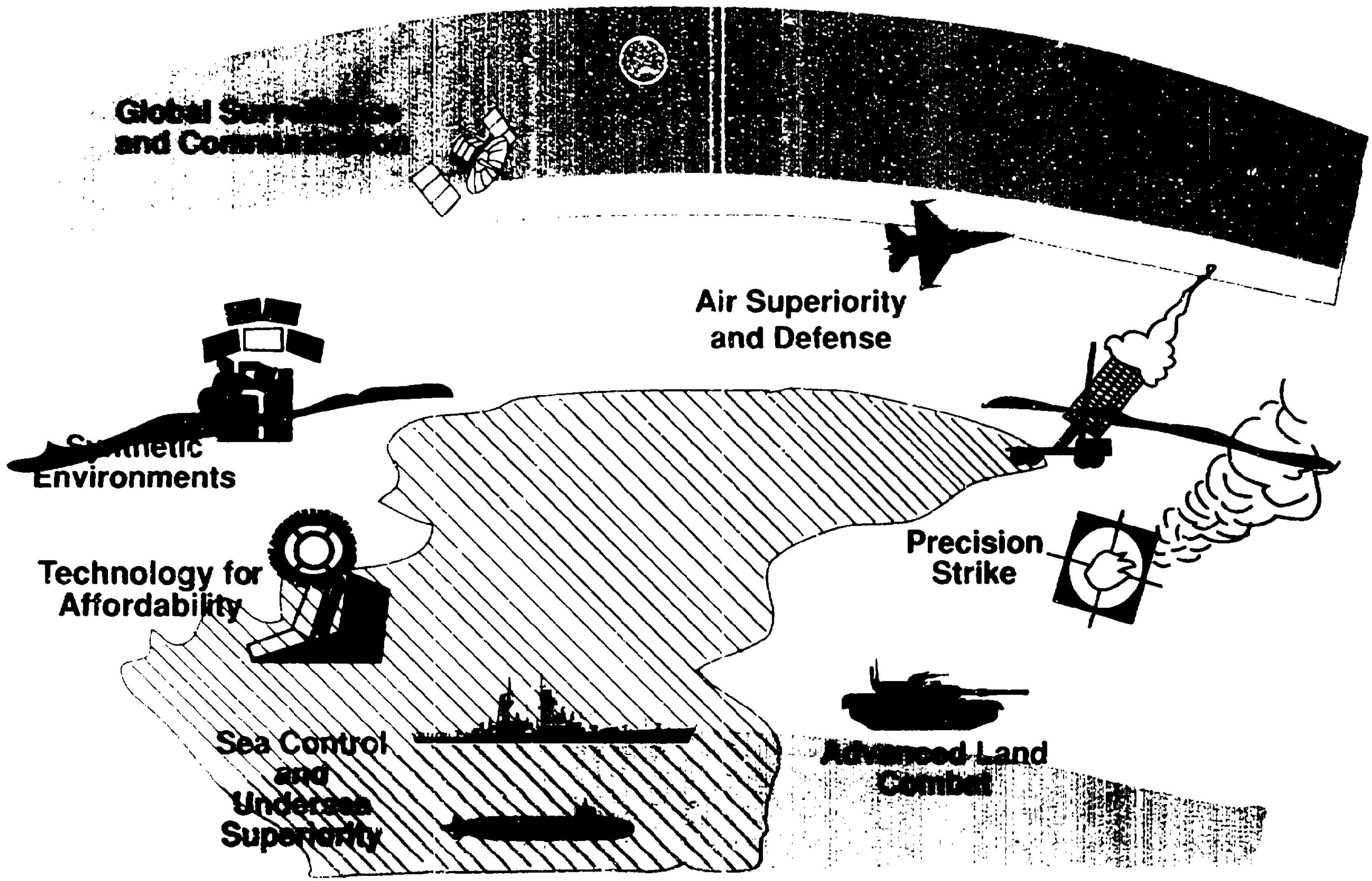
Key Technology Areas. The final chart and text for each Thrust describe the important technological advances that must be emphasized in order to support the ATDs.

Technology Roadmaps. The top-level guidance for each Thrust represents a first cut at laying out some details of the new S&T strategy (which is itself part of a new and unfolding acquisition strategy). The DDR&E, in close cooperation with the Services and Agencies, continues to work on the Technology Roadmaps for each Thrust. Much work remains to be done to refine the details, particularly as the challenging task of implementing the new strategy continues. One of the purposes of this document is to clarify the current status of the S&T strategy as a foundation on which the more detailed implementation plans will be built.

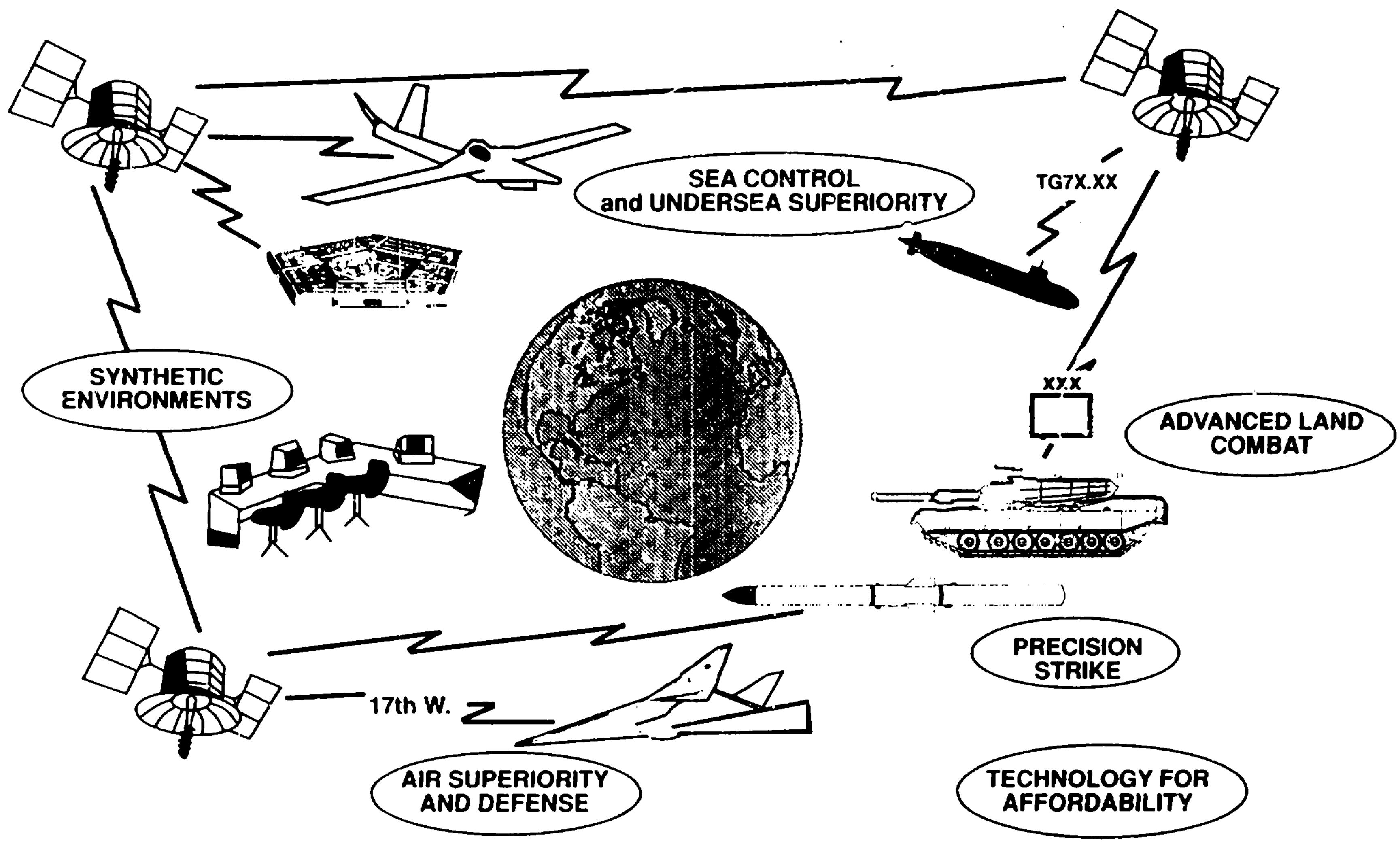
Another important factor concerning the guidance in the following pages is that it includes both a coherent ordering of on-going 6.3A programs (ATDs) and new efforts that recently have been added to those program. As the details of the new S&T strategy continue to be developed, programs and dollars will no doubt change as priorities evolve.

These factors are being emphasized here to remind the reader that much work remains to be done. The DDR&E encourages contributions that will help to refine the program. The Services and Agencies, who must implement and execute this strategy, are equally eager to ensure that their programs meet the Department of Defense's highest priorities.

The Seven S&T Thrusts



1. Global Surveillance and Communications



1. Global Surveillance and Communications: *Legacy*

This Thrust will develop the global aspects of emerging surveillance and communications capabilities. It will contribute to the seamless exchange of information with more local communications and sensing systems described in several of the other Thrusts, particularly Precision Strike.

System of Systems. The Joint Task Force Commander needs to be supported with a "system of systems" for surveillance and communications. This system must function across the Services and Agencies for air, space, sea, and ground operations. It must be scalable from support unit to theater level, as well as robust, flexible, reconfigureable, transparent, and affordable. This concept will provide an overall architecture that will permit the capabilities inherent in all of the Thrusts to interact effectively. It must be capable of carrying out surveillance of the earth at regular, useful intervals, with a capability to focus on any one area as needed. It must convey essential information to intelligence, command and control (C2) systems, and fighting forces with timeliness and accuracy for effective mission execution.

The properties of the system include: (1) expanded surveillance, communication, computing, and reference data capabilities, integrated with the other theater functions directly supporting the joint force commander and interacting with support and higher command in CONUS; (2) C2 integrated with the surveillance and communications systems and reference data so that decision options may be developed (and simulated) within engagement timelines; (3) user-friendly, distributed systems providing robustness with graceful degradation, multimedia sensing, and communication capability; (4) surge capability and the ability to rapidly partition sensing, data processing, exploitation, fusion, and dissemination on a global to subgrid to unit basis, through encryption systems and standards; and (5) responsive unmanned air vehicles, spacecraft, and launch systems.

The system must be able to provide users with a comprehensive global view appropriate to the level of operation of each, permitting the user to interact with *information* as required. This will provide a true, real-time picture of the warfighter's battlespace, thus enabling the allocation of the right forces to the right place at the right time. System operation will appear "seamless," and will be responsive to the user's needs. There are three subordinate, major areas of effort: sensing, communications, and command and control.

Sensing. The sensor system will be globally available, adaptive, focusable, and threat reactive. Through a multitiered approach, sensors will have the ability to search and detect over wide areas, and to focus on smaller areas for target recognition, identification, accurate location, and assessment of mission success (as in battle damage assessment). The effect will be to have an integrated "sensor to shooter" capability.

Communications. The integration and networking of multiple transmission media, hardware, and software will allow essential information to be conveyed quickly and accurately for effective mission execution. Connectivity will be transparent and user friendly. This interoperable and survivable surface-air-space system, utilizing commercial and DoD systems, will be a global grid. There will be extensive sharing of sensors, communications, and other key development efforts with the other Thrusts.

Command and Control. The command and control system will fully integrate surveillance data into the tactical picture to provide timely, accurate, consistent information at all levels of command. It will provide simulation and planning systems, decision systems, human-system interfaces (e.g., displays), and data and information fusion. It will thus allow the decision maker to rapidly observe, evaluate options, decide, and act to ensure that our reaction and cycle times are faster than those of the adversary.

1. Global Surveillance & Communications: *Legacy*

Today	*2000-2005: Potential Via S&T*
• Separate systems - Segregated tasking by system - Restricted area coverage - Limited flexibility in mission, sensors, and reference data	• Integrated systems with expanded broad area sensing - Integrated tasking - Precision, all-weather sensing through mission assessment for multiple missions - Access to extensive reference data
• Independent communications networks and systems with ad hoc interconnects - Limited capacity - Independent data services	• Very high capacity global backbone - Interoperable across ground, sea, space, and air - Multimedia services - Multilevel security
• Barriers between opera[illegible], and intelligence	• Seamless flow of intelligence
• Limited surge - Independent systems C2, planning	• Rapid surge, deployable worldwide - "System of systems" operating on a global grid - Integrated systems C2, planning, simulation

II-1-1

1. Global Surveillance and Communications: *Functions and Goals*

System Concept. The sensor systems will search for and detect targets, recognize and identify them, and assess mission success (e.g., battle damage assessment, BDA). The communications will be scaled and partitioned to permit the optimization of information flow. Platforms can be space-based, airborne, surface-based, or sub-surface. Mission management command and control systems will interconnect knowledge bases, sensors, and warfighters to permit putting weapons on a target while avoiding or suppressing hostile counter-fire and providing a path for anti-fratricide, IFF (information friend or foe) and BDA.

Global Surveillance. The global surveillance system will consist of a wide range of sensors on different platforms that will allow for the collection of a variety of parameters. The system will provide for improved wide area, all weather coverage, with the ability to focus rapidly onto a specific area as needed, with improved geographical accuracies utilizing global positioning system (GPS) coordinates. An expanded set of instruments will measure a wider range of parameters, thus providing increased capabilities in areas such as detailing obscured targets and mapping.

Global Communications. Global communications consists of the hardware and software open system architectures that will provide the connectivity for the global surveillance system. The hardware architecture can vary from narrowband to very wide band on point to point through multicast circuits. They will be adaptable, affordable, flexible, robust, and survivable general purpose networks. They will be able to accommodate unique subnets configurable to user requirements and will possess a fully integrated mix of media providing a wide variety of services.

Communications architectures will allow centralized coordination with decentralized control and execution. They will also be self-healing if links are broken or jammed, or if subsystems are damaged or fail. The system will be quickly reconfigurable and fully integrated among the networks. The software architecture will be built upon a multilevel secure (MLS) base that will be able to tie into the intelligence community and interact with the resources of allies. The system will provide flexible access to extensive computing resources that will allow for distributed processing for information fusion, simulation, training, and logistics as the Joint Task Force Commander deems appropriate.

Command and Control. Command and control will prepare decision makers for periods of crisis and war through simulations. With the extensive computing and database resources available, a commander can consider a wider range of options—and review "war games" of those options—prior to execution on the battlefield. This will enable the commander to respond effectively and efficiently to new opportunities. The C2 system will also provide multiple command levels with the appropriate surveillance and reference data. This ability to adjust the data to the level of command will be a key function. The simulation of surveillance and communication will be integrated across the other Thrusts.

Reference Data. The global surveillance system will work with the appropriate reference data, such as maps and environmental and background signatures, to ensure that the appropriate sensor is used for a given task. Reference data also will allow the products to be represented to the user in the context of the current situation and will allow the user to interact and manipulate the data in preparing for the next maneuver.

Affordability. Lower costs throughout the R&D and manufacturing phases will be achieved by emphasizing new, flexible production methods, standardization, and modularity. The more effective focus and use of the country's R&D infrastructure, to include cooperative endeavors with the commercial sector, will be addressed. The rapid demonstration of the potential capabilities of specific technologies will be emphasized.

1. Global Surveillance & Communications: *Functions & Goals*

Functions	*Goals*
• Global Surveillance And Intelligence	• Area rate coverage significantly improved High accuracy, rapid availability Integrated with GPS coordinates Expanded sensing attributes: penetration, resolution, multiparameters, focusable, rapid 3-D mapping
• Communications	• Worldwide multigigabit grid transparent across ground, air, space, and sea systems Surge via ground fiber, UAVs, space systems Flexible access to: - Extensive computing resources - Multimedia, multilevel security - Commercial commun. and equip. via "key" standards
• Command And Control	• Seamless flow from training to operations Pre-execution simulation of options and conditions Electronic reconfigurable levels of information/command flow
• Reference Data	• Flexible, heterogeneous access to maps, documents, environmental sensing archives, joint data dictionary Training available "on-demand"
• Affordability	• Lower cost through flexible production, standardization, and modularity

1. Global Surveillance and Communications: *Top-Level Demonstrations*

The Global Surveillance and Communications demonstrations are to be conducted in parallel to provide validated information that will be integrated into the ongoing simulation efforts that span the seven S&T Thrusts, as well as other DoD and related areas. This will provide ever-increasing validity and completeness to the simulations, which in turn will provide a better focus for follow-on demonstrations.

There are three broad classes of demonstrations, representing (1) architectures, simulation and command and control functions, (2) specific "system demonstrations" (e.g., an EHF satellite), and (3) technologies and manufacturing initiatives. Conducting demonstrations in this manner will provide, by the end of the decade, the architecture and tested capabilities and features, combined with the new "breakout" technologies, that can lead to "Revolutionary Functional Capabilities."

Demonstrations are planned for sensors, platforms, communications, reference data, command and control, and integrated systems (i.e., sensors and platforms integrated with the weapon systems). The key capabilities to be evaluated during the demonstrations are sensor-to-shooter hand-off, battle damage assessment, focusability, and the interoperability with real command and control and a wide range of communications capabilities.

The use of common buses is supportive of the sensor and communications concepts, as is the use of bolt-on modular payloads. Flexible production concepts will be examined for their applicability to high-reliability, low-rate production. Standard gateways will be demonstrated that provide low cost access to the commercial communications world. Adaptable network control will allow for the optimal shared use of resources to serve unique subnets for the time needed.

Flexible Architectures/Simulation. Automated battle simulation in real and near-real-time, at many echelons, is a future capability. This demonstration will be rapidly developed to permit evaluation of the various architectures and sensor systems across all the Thrusts. An integrated demonstration between the Global Surveillance and Communications and Precision Strike Thrusts is scheduled for 1998.

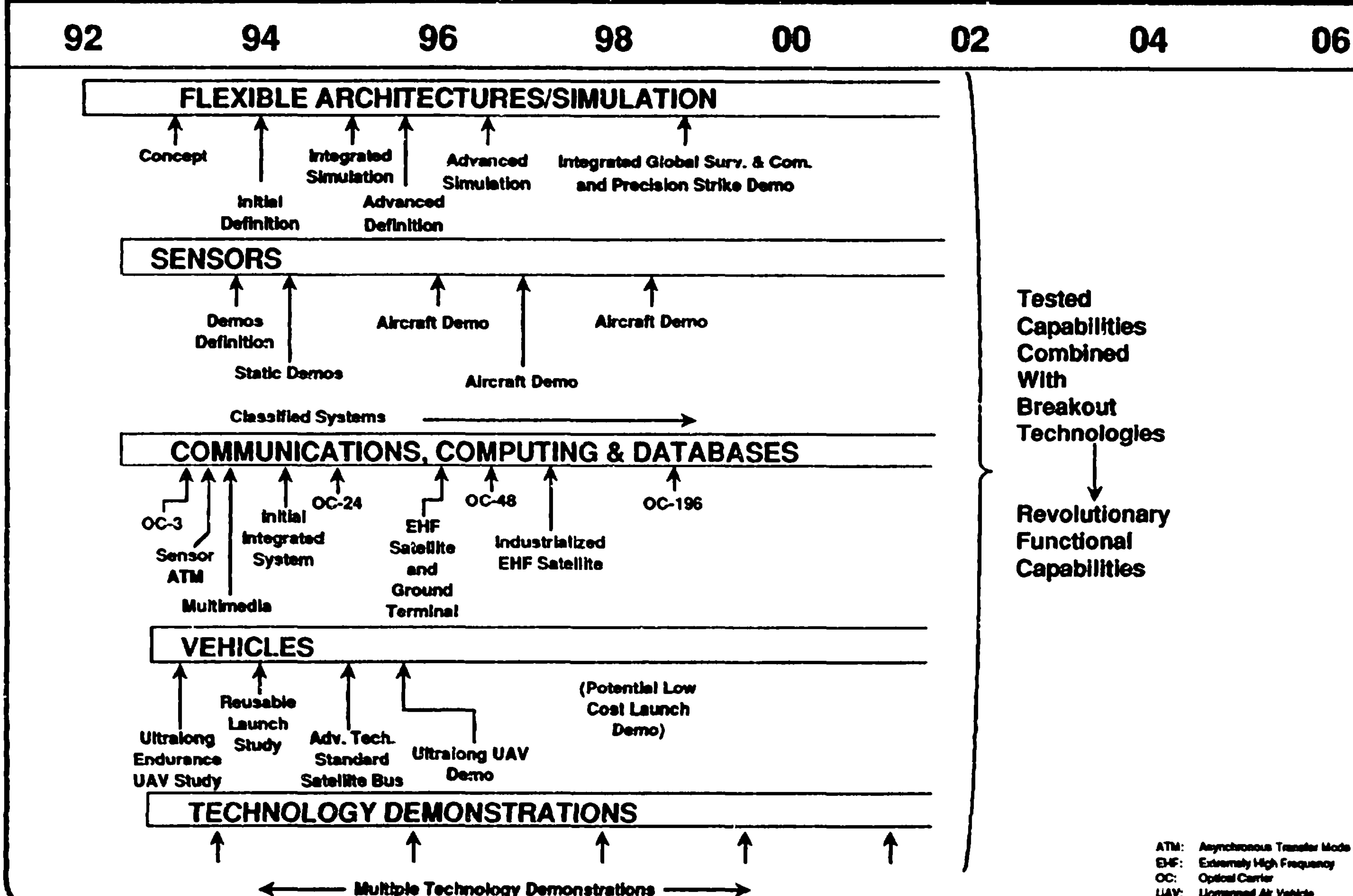
Sensors. This demonstration will be used to develop understandings of expanded sensor capabilities against shortened decision times for command and control and data dissemination. The demonstrations will evolve from static through integrated surveillance demonstrations with classified components. The standardization of interfaces based on commercial telecommunications protocols and fiber optic interconnects will be demonstrated.

Communications, Computing, and Databases. Early emphasis will be placed on demonstrating advanced communications technology, standardized payload modules, and interoperable high rate communications systems usable in other Thrusts. Switched Telecommunications Standards (e.g., ATM/SONET) will be demonstrated with encrypted services for multimedia, multisource information from sensors to computers.

Vehicles. Vehicles to provide the responsiveness in costs and time—ultra-long endurance UAV and reusable launch systems—will be examined for technical and operational potential.

Technology Demonstrations. Other specific technology demonstrations will focus on key or breakout technologies that will enable more aggressive or lower cost system capabilities when inserted into new and existing systems.

1. Global Surveillance & Communications: *Top-Level Demos*



1. Global Surveillance and Communications: *Key Technology Areas*

Surveillance. Large-area-coverage attributes require very high-speed, low-power sensors. Advanced techniques for compressing data and limiting or finding initial information are needed. Sensors must be developed to detect targets that are in complex environments—both of natural and man made origin—and for evolving targets and threats. Advanced computing and software capabilities are needed to handle very large amounts of data in near real time, as are miniature electronic devices which minimize manual testing and integration, such as MIMIC (Millimeterwave and Microwave Monolithic Integrated Circuits). Similarly, photonics and high temperature superconductors need to be pursued for their attributes. As far as possible, common protocols and media should be used to obtain interoperability (e.g., ATM/SONET).

Communications. A range of communications network technologies are required, from very wide band communications (multiple gigabits/sec) for moving large amounts of information rapidly between tens of users, to low rate (hundreds of bits/sec) interactions with many thousands of users. International commercial telecommunications standards (e.g., ATM/SONET) should be used, and switching systems must support features such as multicase dynamic bandwidth location, subgrid partitioning, and encryption. Further, the systems must provide the required end-to-end survivability needed for critical military functions. The encryption technologies need to be electronically reconfigureable and supportive of packet switched systems. Data comparison that is scalable to the users' needs are required. Communications systems that are common across surface, air, and space platforms, as well as controllable in wave forms, are needed to ensure interoperability.

Command and Control. Human-machine interaction technologies are needed that permit distributed decision making with the effective use of very large amounts of data. An ability to reconfigure extensive resources for collecting and manipulating communications and string data, such that personnel demands are minimized, is needed. Technologies to assess the risk in executing various options available to the warfighter are required. Large scale synthetic environments are needed that support a range of functions, transitioning from training to execution at variable rates from less than real-time to many times real-time.

Platforms. Technologies to significantly lower the cost of spacecraft, UAVs, and launch systems are needed. These range from materials issues to technologies that will reduce infrastructure support and producibility costs.

1. Global Surveillance & Comm.: *Key Technology Areas*

FLEXIBLE ARCHITECTURE/SIMULATION

1. Computers	5. Electronic Devices
2. Software	10. Design Automation
4. Communications Networking	11. Human-System Interfaces

SENSORS

1. Computers	5. Electronic Devices
2. Software	6. Environmental Effects
3. Sensors	7. Materials and Processes

COMMUNICATIONS, COMPUTING, AND DATABASES

1. Computers	4. Communications Networking
2. Software	5. Electronic Devices

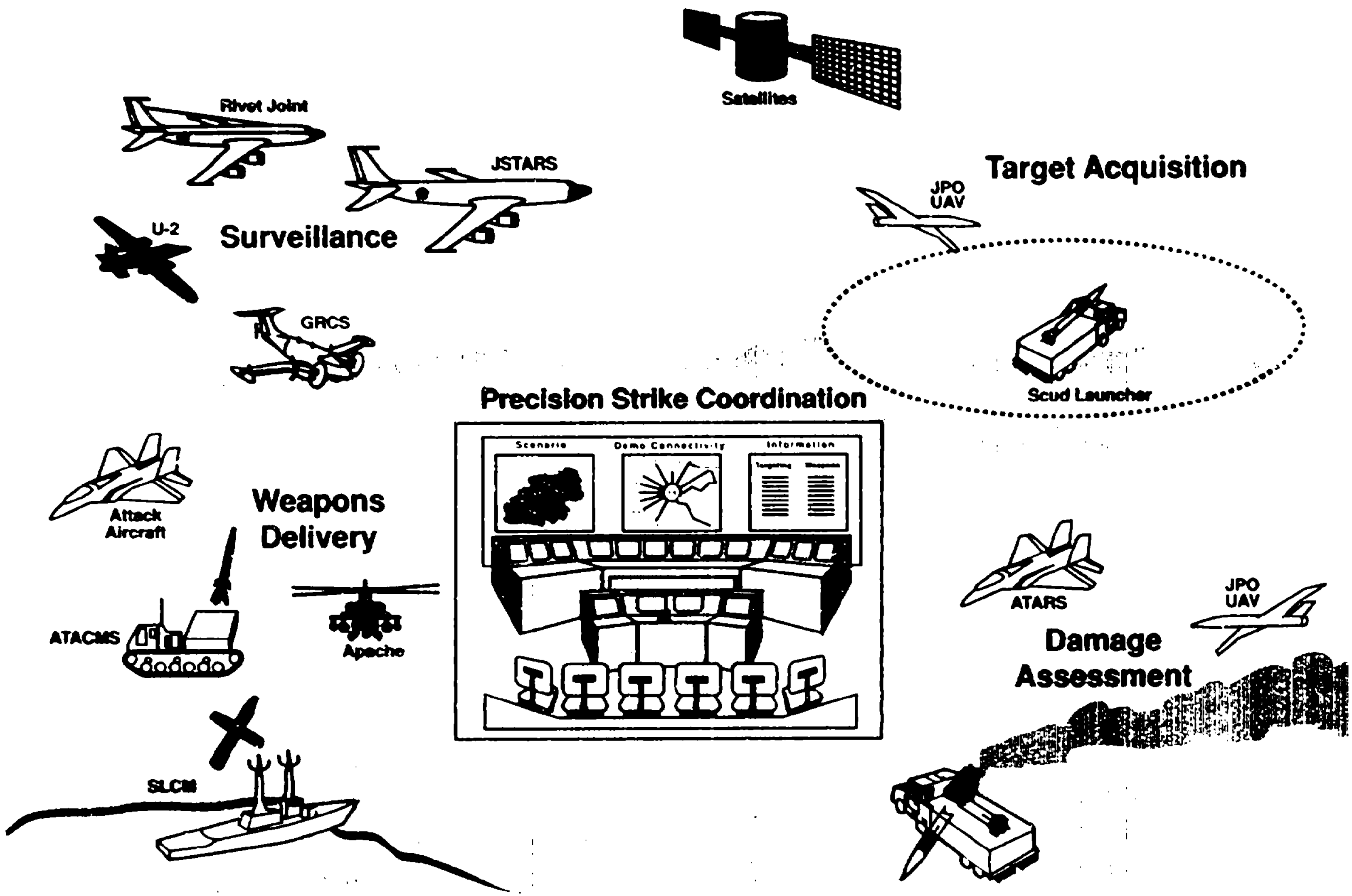
VEHICLES

1. Computers	7. Materials and Processes
2. Software	9. Propulsion and Energy Conversion

TECHNOLOGY DEMONSTRATIONS

1. Computers	5. Electronic Devices
3. Sensors	6. Environmental Effects
4. Communications Networking	7. Materials and Processes

2. Precision Strike



2. Precision Strike: *Legacy*

Precision Strike is a set of integrated, multi-Service capabilities for locating, identifying, and killing high-value, time-sensitive military ground targets. This detection-engagement cycle must be executable in all weather conditions, day or night, with precision accuracy, and in timely response to the commander's operational needs. *Success in Precision Strike depends on achieving a seamless interface with Global Surveillance and Communications systems.*

Extreme accuracies and all-weather, day/night capabilities will be developed in the Precision Strike Thrust. The program will exploit on- and off-board sensor cues for a real time, flexible precision strike capability, and address the time and distance constraints challenging a genuine precision strike capability. Precision strike integrates surveillance, target acquisition, strike/mission planning, weapons delivery, and battle damage assessment and will enable commanders to neutralize targets critical to their operational plans.

Today. Currently the Services have fielded, or are developing, excellent surveillance and strike sensors, such as the Joint Surveillance and Target Acquisition Radar System (JSTARS), Advanced Synthetic Aperture Radar System (ASARS), and the APG-70, which embody technology that can be upgraded to address stressing targets. Existing lethal long-range weapons such as the Army Tactical Missile System (ATACMS), aircraft-delivered precision-guided munitions (PGMs), and Tomahawk Land Attack Missiles (TLAMs) also can be upgraded. However, outside the immediate battle area, today's strike systems generally depend on a target detection, location, mission planning, and attack process which takes more time than may be available when engaging time-sensitive fixed and mobile targets such as cruise and ballistic missiles fired from "shoot and scoot" launchers.

Experience in hunting Scuds during Operation Desert Storm highlighted several problem areas in attacking time-sensitive targets. Deficiencies include: a cumbersome joint strike planning process with slow and disjointed surveillance tasking, target selection, and planning functions; slow dissemination of surveillance data which often requires "sanitizing" before it can be made available to strike/mission planners; sensors and weapon seekers restricted by weather, day/night, or foliage and camouflage penetration deficiencies; and delayed post-strike damage assessment.

2000-2005: Potential. The solution to the time-sensitive target engagement problem is an integrated joint precision strike system-of-systems that can routinely detect, attack, and destroy enemy forces. Surveillance must provide direct and immediate input to the strike/mission planning and weapons assignment process. To meet stringent weapon delivery timelines, surveillance systems will pass target data directly to the strike/mission planners who, if need be, can send that same information directly to the appropriate weapon delivery systems and munitions.

Extended range weapons and dynamic sensor and weapons retasking will enhance a quick-reaction kill capability. Sensors and weapon seekers contributing to the end-to-end capability must provide all-weather, day and night, and foliage obscurant penetration capabilities for target identification and immediate post-strike battle damage assessment. Enhanced human-machine interfaces within the total precision strike capability will result in improved data assimilation, decision making, targeting, and damage assessment. The penetration of hardened facilities with adequate lethality upon penetration will be pursued. Damage assessment capabilities will be responsive to non-lethal as well as lethal weapons effects.

2. Precision Strike: *Legacy*

Today	*2000-2005: Potential Via S&T*
• Some good sensors/weapons, but critical mobile targets hard to find and kill - Limited weapon range or long response time - Limited detection and track capability	• Joint, integrated, all-weather precision strike system-of-systems capability - Reliable detection and track capability - Flexible mix of weapons capabilities with adequate response times
• Cumbersome joint strike/mission planning - Unable to operate inside target timeline - Sensor/weapon retasking unwieldy	• Joint quick-reaction kill of time-sensitive targets - Operate within target timeline - Dynamic sensor/weapon retasking
• Slow dissemination of surveillance data/imagery, intel, and force orders	• Interoperable, timely, on-demand dissemination to operators
• Limited day/night/all-weather/foliage and camouflage penetration	• Day/night operations through foliage, camouflage, and obscurants
• Slow battle damage assessment, limited by weather	• Immediate battle damage assessment in all weather

2. Precision Strike: *Functions and Goals*

FUNCTIONS. Precision strike functions today are performed sequentially, by different agencies and at different levels, and with weather restrictions. An important goal is to provide feedback that will allow operational communities to re-examine organizational, operational, and structural concepts that currently cause inefficiencies. Also important is the development of technologies to provide "feed-forward" information for the implementation of improved or new precision strike functions.

Surveillance. Wide area surveillance must be provided over the entire operational area, to include theater ballistic missile launch areas.

Target Acquisition. Multisensor data must be fused and analyzed to identify targets and provide data to mission planners and weapons systems.

Strike/Mission Planning. Strike/mission planners must prioritize targets, select appropriate weapons and delivery systems, and assign tasks. They must plan and coordinate weapons platform routes to and from engagement areas.

Weapon Delivery. The weapons delivery platform must receive target information in sufficient detail to locate, identify, track, and release weapons into appropriate delivery "baskets."

Weapons Guidance. The weapons guidance system must place the warhead on target, in time, and with lethal accuracy.

Battle Damage Assessment. Both the commander and the strike/mission planners must know if the target is destroyed—and if not, what re-strike is needed.

Centralized Coordination, Decentralized Execution. The surveillance, target acquisition, strike/mission planning, weapons delivery, and damage assessment functions must be integrated in a system-of-systems that permits the centralized management of precision strike to develop target sets and decentralized execution to kill the targets.

GOALS. A joint, precision strike, end-to-end, system-of-systems approach will be a seamless, integrated capability that supports the joint commander's needs to locate, identify, and kill designated high-value targets with precision.

Continuous Update of Situation. Surveillance must be constant to maintain coverage of the area of influence in order to detect, identify, and accurately locate potential targets to support engagement within stringent timelines.

Acquire Target Data. Sensor data must support the programming of selected strike systems and their weapons with target location and signature information. Updated target track, location and configuration data, and re-target tasking must be communicated to weapons systems.

Integrate Information. All situational data must be integrated so that strike/mission planners throughout the theater have ready access to all pertinent data for their conduct of the battle.

Unconstrained, Rapid Weapon Delivery. The weapon delivery platform sensors and weapons seekers must be able to operate with precision under adverse weather conditions, during day or night, and against time-sensitive, concealed targets. In addition, lethal attacks must be timely. To reduce launch and flyout times against short dwell targets, hypervelocity missiles or platforms with long loiter times may be required.

Assess Damage. Assessments of strike effectiveness must be available to the delivery platform and mission planners in time to permit immediate decisions concerning re-strikes.

Secure Communications and Distributed Data Processing. Real-time secure communications, distributed on-line data processing, and feedback loops are essential for integrating the precision strike functions. All nodes must have all required information to execute their portion of the battle in a responsive manner.

2. Precision Strike: *Functions & Goals*

Functions	*Goals*
• Surveillance	• Near-continuous broad area coverage with on-demand area focus
• Target Acquisition	• Rapid target acquisition and high quality track-to-weapon handoff
• Strike/Mission Planning	• Ability to integrate information, set priorities, assign targets
• Weapon Delivery	• Unconstrained and timely weapon delivery
• Damage Assessment	• Immediate damage assessment feedback
• Centralized Coordination Decentralized Battle Execution	• Precision strike nodes linked with real-time secure communications and distributed data processing

2. Precision Strike: *Top-Level Demonstrations*

Background. The desire for reduced casualties, economy of force, and fewer weapons platforms demands that we locate targets and destroy them with accuracy and timeliness. The emphasis is on finding and prosecuting time-sensitive fixed and mobile targets employing robust concealment, camouflage, and deception techniques in all types of terrain and weather.

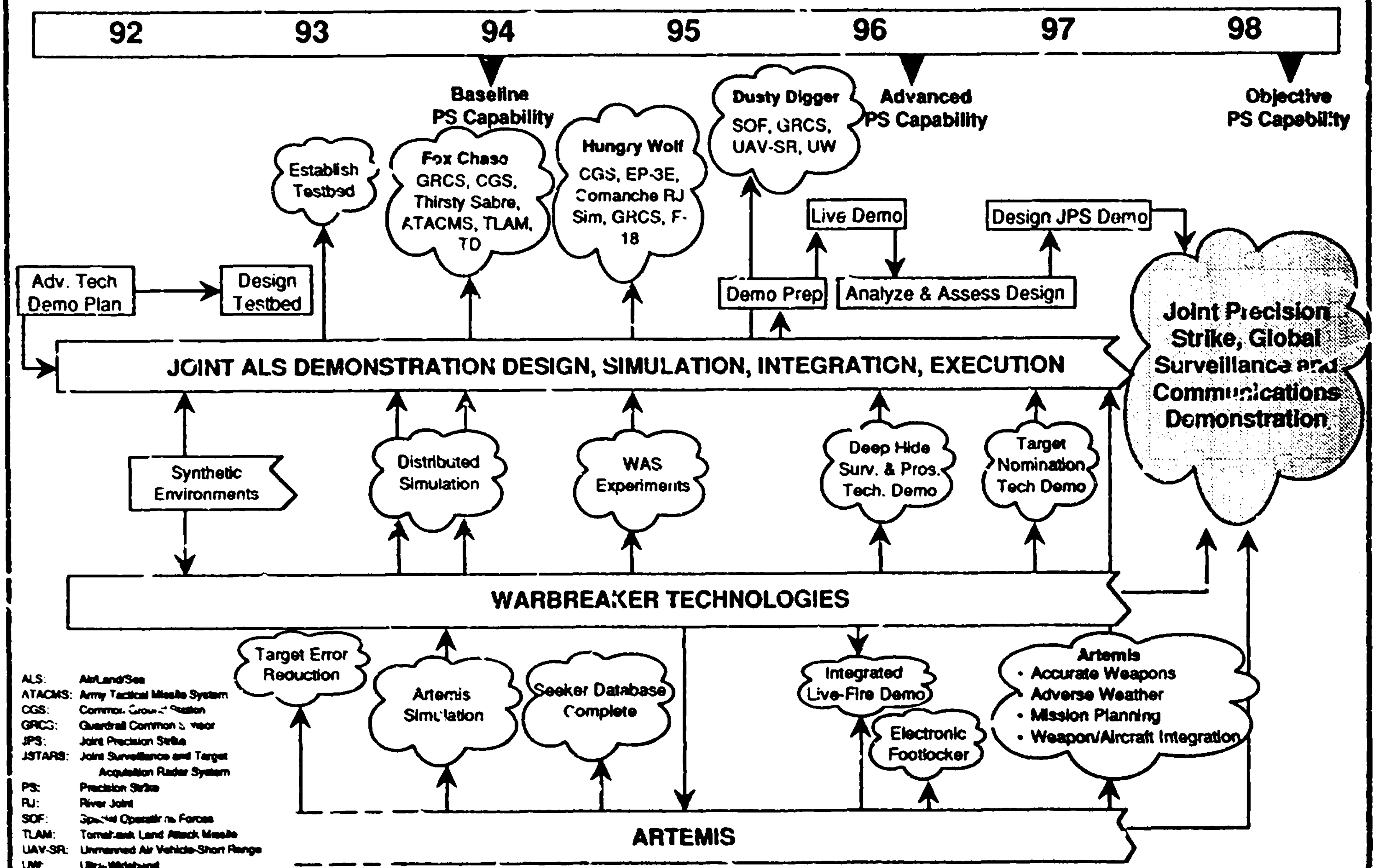
Many of the challenges to developing an effective joint precision strike capability are organizational, doctrinal, and/or structural. An important objective of the Precision Strike Thrust, therefore, is to demonstrate that operational considerations and inter-Service concerns can be fully and completely addressed. In addition to test data, new technology, and feedback for use by operators as they develop the doctrine for conducting joint precision strike operations, the demonstration will provide a distributed simulation testbed that can be used for evaluating technologies and operational concepts. Three top-level efforts are currently identified under the Precision Strike Thrust: the Joint Air/Land/Sea (ALS) Precision Strike Demonstration, Artemis, and Warbreaker. Under the Precision Strike Thrust, a series of demonstrations will be conducted between 1994 and 1998, leading to an expanded precision strike capability in the post-2000 time frame.

Joint Air/Land/Sea Precision Strike Demonstration. The joint ALS program will validate emerging technologies and concepts through a series of demonstrations in an operational environment, leading to an objective integrated precision strike capability. Beginning in FY 1993, the Joint ALS program will plan for and coordinate a series of demonstrations that feature real and simulated Army aviation (Apache Longbow and Comanche) and longer range field artillery (ATACMS), along with Navy and Air Force capabilities in an end-to-end precision strike system. In FY 1996, the joint ALS program will conduct an advanced precision strike capability demonstration. In FY 1998, it will coordinate an objective integrated demonstration with the Global Surveillance and Communications Thrust, the Synthetic Environments Thrust, and the Artemis and Warbreaker programs. A Joint Precision Strike (JPS) Testbed will be established to coordinate the JPS demonstrations. The fundamental building block for the JPS Testbed is the Warbreaker-developed distributed simulation capability, which will begin an incremental transition to the testbed in FY 1993.

Warbreaker. Warbreaker is a focused effort to develop and demonstrate enabling technologies and advanced systems to support the objectives of the Precision Strike (and Global Surveillance and Communications) Thrust. The technologies, which are harmonized with related Service technology efforts, include an automated, distributed intelligence correlation system to support rapid target nomination; an automated mapping system incorporating advanced terrain data generation technologies; and advanced sensors and processing supporting automatic target detection and recognition of "deep hide" targets employing heavy camouflage, concealment, and deception (CCD). A distributed wargaming simulation (WARSIM) will be developed as a systems engineering tool to focus the Warbreaker and synthetic environments technologies in an integrated system context.

Artemis. The Artemis program will develop and demonstrate an affordable capability, to include mission planning, to deliver conventional weapons against time-sensitive fixed and mobile targets, day or night, in all weather, with precision accuracy (less than 3 meters CEP), utilizing on-board and off-board near-real-time targeting data. In FY 1994 a simulation of Artemis will be conducted in support of the joint precision strike demonstrations. Field demonstrations will begin in late FY 1996, to be integrated with the Joint ALS and the integrated Joint Precision Strike and Global Surveillance and Communications demonstrations.

2. Precision Strike: *Top-Level Demonstrations*



ALS: Air/Land/Sea
ATACMS: Army Tactical Missile System
CGS: Common Ground Station
GRCS: Guardrail Common Sensor
JPS: Joint Precision Strike
JSTARS: Joint Surveillance and Target Acquisition Radar System
PS: Precision Strike
RJ: River Joint
SOF: Special Operations Forces
TLAM: Tomahawk Land Attack Missile
UAV-SR: Unmanned Air Vehicle-Short Range
UW: Ultra-Wideband
WAS: Wide Area Surveillance

2. Precision Strike: *Key Technology Areas*

Computers. High-performance (speed and capacity) computer capabilities to support near-real-time targeting will be the cornerstone of the testbed supporting Precision Strike. Advanced automation will enable the testbed to perform its functions in a real and/or simulated environment. Sensor systems will provide the testbed with targeting data which, when paired with other status data such as potential attack platform locations, will produce the appropriate, timely weapon solution to address the target. Also important for precision strike are sensor data, signal processing, and fire control solutions.

Software. Precision strike demonstrations will utilize actual sensors, weapons, and their associated data when feasible. For those systems that will not be available, advanced distributed simulation will link system models into the testbed. This will enable us to demonstrate precision strike scenarios on a combined arms electronic battlefield using both real and simulated capabilities.

Sensors. Critical sensors and weapons possess a combination of computer architectures, algorithms, and microelectronic signal processing devices for the near-real-time automation of detection, classification, and tracking of time-sensitive targets. Radar sensors capable of detection, non-cooperative classification, recognition, and/or the identification of precision strike targets will be key components of an integrated joint precision strike capability. Passive sensors such as signals intelligence (SIGINT) systems and electro-optical (EO) and infrared (IR) detectors also will be major contributors.

Electronic Devices. Materials and processes for developing and producing integrated high density electronic components and packaging are essential to precision guided munitions, on-board automatic target recognition equipment, processors, and advanced sensors and seekers that will be utilized in the Artemis and Warbreaker demonstrations.

Environmental Effects. The automated generation of near-real-time environmental tactical decision aids to determine the effects of adverse battlefield environments on sensing and correlation are critical for optimized, mission-specific sensor and platform assignments, weapon-target pairings, and parameterization of target detection and recognition algorithms. Technical challenges are the exploitation of near-real-time weather data, automated terrain reasoning, modeling of terrain and environmental signatures in the visual, millimeterwave (MMW), and IR domains, and the development of comprehensive environmental databases.

Materials and Processes. Low observables, resistance to thermal dynamic heating, high structural loading integrity, and affordable manufacturing processes are crucial for advanced weapon systems.

Energy Storage. Explosives are needed that fulfill the requirement for insensitive munitions and provide the means to destroy the target. High energy density explosives increase the permissible distance by which a PGM may miss and still deliver its lethal mechanism. Higher energy density propellants increase the stand-off distance from which the munition may be launched.

Propulsion and Energy Conversion. Advances in weapon system propulsion and energy conversion technologies will be critical to overcoming the time and distance obstacles to attacking time-sensitive targets at extended ranges.

Human-System Interfaces. Decision aid software will incorporate aspects of artificial "intelligence" in precision strike capabilities. State-of-the-art human-system interfaces and displays will be incorporated and evaluated in the testbed to determine their value added in the rapid decision making process required for joint precision strike operations.

2. Precision Strike: *Key Technology Areas*

AIR/LAND/SEA DEMONSTRATION

1. Computers
2. Software
3. Sensors
4. Communications Networking
5. Electronic Devices
6. Environmental Effects
7. Materials and Processes
8. Energy Storage
10. Design Automation
11. Human-System Interfaces

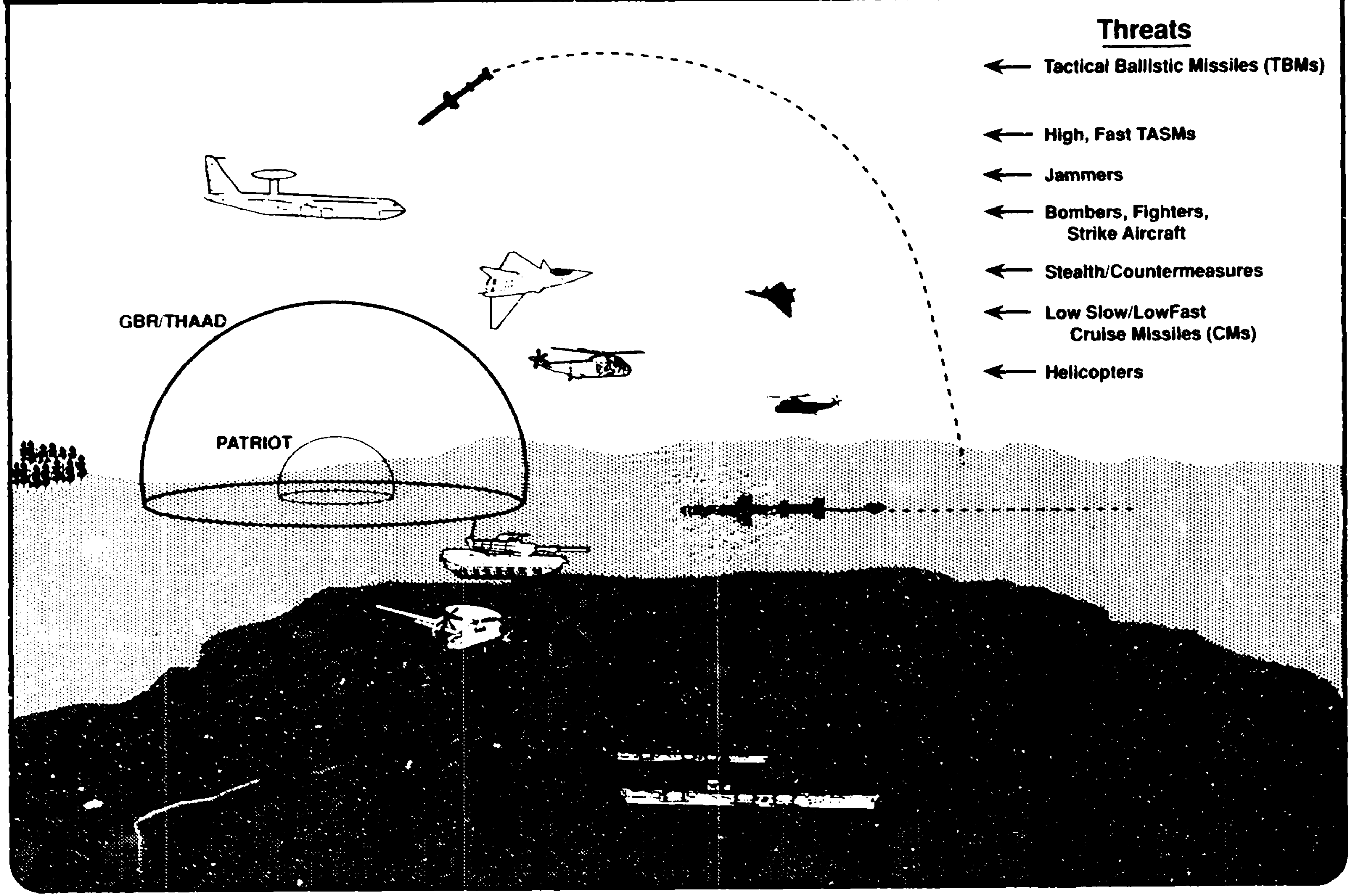
WARBREAKER DEMONSTRATION

1. Computers
2. Software
3. Sensors
4. Communications Networking
5. Electronic Devices
6. Environmental Effects
7. Materials and Processes
11. Human-System Interfaces

ARTEMIS DEMONSTRATION

1. Computers
2. Software
3. Sensors
4. Communications Networking
5. Electronic Devices
6. Environmental Effects
7. Materials and Processes
10. Design Automation
11. Human-System Interfaces

3. Air Superiority and Defense



3. Air Superiority and Defense: *Legacy*

The S&T strategy for the Air Superiority and Defense Thrust will be to develop and demonstrate technologies providing a dramatically improved or completely new capability to defend against and engage tactical ballistic missiles (TBMs) and stealthy manned aircraft, cruise missiles, and helicopters.

Today, our only system with a capability against tactical ballistic missiles is Patriot PAC-2. Notwithstanding its success in the Persian Gulf War, the system has a very limited defended footprint and has no capability against longer range TBMs and higher density attacks. The planned Patriot PAC-3 and ground-based radar (GBR) and theater high altitude air defense (THAAD) programs will demonstrate and field very credible point and area defense capabilities against TBMs up to 3000 km in range. The associated S&T strategy will be to build upon this foundation to demonstrate enhanced capabilities against future threat developments, including reduced signature and mass destruction warheads.

The Persian Gulf War demonstrated our formidable air superiority over conventional manned aircraft. Our concern is the projected emergence of stealthy manned aircraft and cruise missile threats that would eliminate this advantage and dramatically reduce the battlespace of current defensive weapon systems. The S&T program will demonstrate a series of technologies that will preserve today's air defense battlespace and our air superiority.

Currently, there are several areas in which we have very limited or no capability. Our objective is to demonstrate an effective new capability against clutter-embedded and terrain-masked helicopters, as well as naval sea-skimming cruise missiles.

Today our weapon systems operate in an essentially autonomous mode. Under some circumstances there are significant improvements in overall capability that can be gained by netting multiple systems to provide optimal resource allocation and the cooperative prosecution of targets. Our strategy will be to develop and demonstrate the selected netting of systems among multiple service systems in order to provide significantly enhanced capabilities.

3. Air Superiority and Defense: *Legacy*

Today	*2000-2005: Potential Via S&T*
• Limited point defense against low intensity attacks by current TBMs	• Low leakage area defense against future TBMs
• Effective air superiority against conventional aircraft; very limited battlespace against stealthy cruise missiles (CMs)	• Restored battlespace against stealthy aircraft and CMs employing modern countermeasures - All air defense missions - CM area defense
• Minimal short-range defense capability against some targets	• High single-shot Pk agai - Helos in clutter - Terrain-masked helos - Sea-skimming missiles
• Autonomous weapon systems	• Netted systems providing: - Optimal resource allocation - Cooperative engagement

3. Air Superiority and Defense: *Functions and Goals*

The functions required for air defense can be broadly categorized as surveillance, fire control, missile guidance, fuzing, and battle management/command, control, and communications (BM/C3). Significant advances over today's capability will be required in each area. We will require all-weather, day/night engagement of manned aircraft, cruise missile, helicopter, and tactical ballistic missile targets that will be employing increasingly sophisticated stealth and countermeasures.

Surveillance must be performed from both airborne and ground-based platforms and must provide good target identification and discrimination. Downward-looking surveillance sensors will face extremely difficult clutter rejection problems, especially when searching for stealthy targets. Precision track and fire control must also be performed from air and surface platforms. In general, fire control systems will be required to provide mid-course guidance and illumination functions with a higher degree of precision than in today's systems. Cooperative engagement will be required in some situations to allow one fire control system to control and guide missiles launched from other platforms.

Missile guidance will be made difficult by both the high closing velocities of TBMs and the low signatures of airborne vehicles. For short-range applications and against low-cost targets, lower cost rounds will be required. Hit-to-kill technologies must be enhanced and perfected to ensure high lethality against mass destruction warheads, including canistered submunitions.

Finally, it is clear that we cannot afford the luxury of independent TBM defense (TBMD) and air defense architectures. Surveillance and fire control sensors must be designed and operated to mutually support air defense, air superiority, and TBMD missions to the maximum extent practicable.

3. Air Superiority and Defense: *Functions & Goals*

Functions	*Goals*
	General Threat Characteristics: • All weather day/night • Stealthy aircraft, CMs, helos, TBMs • Advanced countermeasures • Targets in clutter
Surveillance	• From air and surface platforms • Reliable target identification/discrimination
Fire Control	• From air and surface platforms • Weapon support • Cooperative engagement
Missile Guidance	• All aspect targets • Fire and forget • Low cost at short range
Fuzing/Target Kill	• High lethality against mass destruction warheads
BM/C3	• Integrated air defense/TBMD architectures

3. Air Superiority and Defense: *Top-Level Demonstrations*

Five high priority areas are being established for the Air Superiority and Defense Thrust. These will provide the foci for specific technology demonstrations.

Tactical Ballistic Missile Defense. The plan for TBMD is to conduct demonstrations of specific technologies and capabilities that will build upon the basic capability now being developed in the Patriot PAC-3 and THAAD/GBR programs. Capabilities to be demonstrated will include a naval capability based on the Aegis weapon system, cueing of THAAD/GBR, and enhanced warhead lethality.

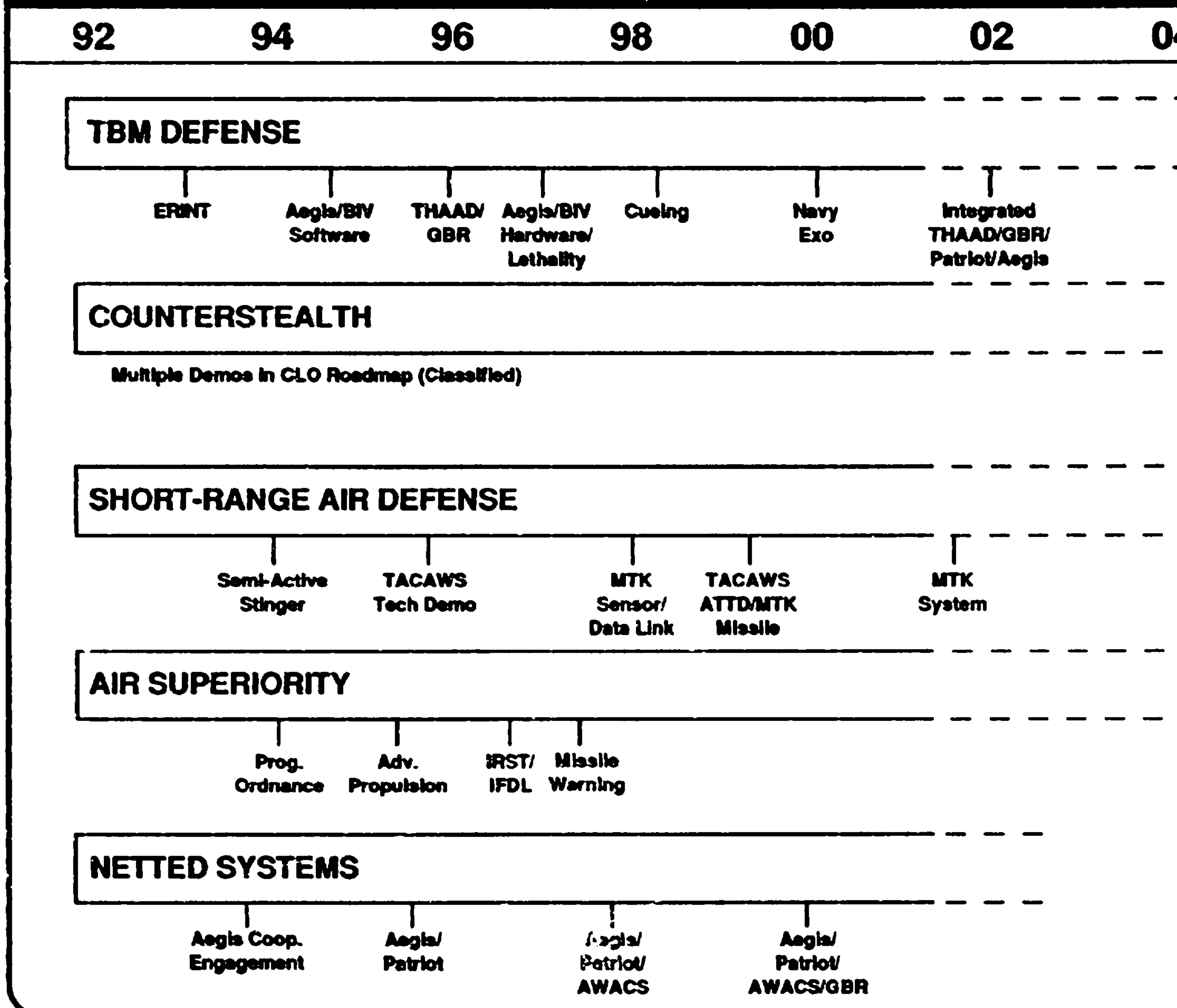
Counterstealth. Counterstealth continues to be a high priority area. Specific demonstrations are addressed in the classified DoD Counter-Low Observables (CLO) Roadmap.

Short-Range Air Defense. A series of short-range air defense demonstrations will be conducted to address current Naval deficiencies against sea-skimming cruise missiles and Army deficiencies against threat helicopters that are terrain-masked or imbedded in clutter.

Air Superiority. The Persian Gulf War demonstrated both the current air superiority enjoyed by the United States and the importance of maintaining that advantage. In this area, a sequence of demonstrations will be conducted that potentially can provide significantly improved capabilities for future tactical aircraft.

Netted Systems. Finally, an increasingly complex series of demonstrations will be conducted to evaluate the potential of netted sensors to improve both surveillance and engagement capabilities.

3. Air Superiority and Defense: *Top-Level Demonstrations*



AWACS: Airborne Warning and Control System
CLO: Counter-Low Observable
ERINT: Extended Range Interceptor
Exo/Endo: Exo/Endo-atmospheric
GBR: Ground-Based Radar
IFDL: Intra-Flight Data Link
IRST: Infrared Search and Track
MTK: Masked Target Kill
TACAWS: The Army Combined Arms WeaponSystem
THAAD: Theater High Altitude Air Defense

3. Air Superiority and Defense: *Key Technology Areas*

Tactical Ballistic Missile Defense. The layered defense systems envisioned for tactical ballistic missile defense will require high-speed signal processing, both for ground-based sensor sites and on-board intercepting missiles. Ground-based radars and missile-borne infrared seekers will require dramatic advances in solid-state modules, focal plane arrays, radomes, and a variety of materials. Higher speed, smaller, and lower cost missile propulsion systems will be required to support the intercept of longer range TBMs.

Counterstealth. The classified program in this area will require a range of critical technological advances to support a number of advanced sensors, weapons, and C3I systems.

Short-Range Air Defense. The most difficult problems in this area include rapid target acquisition in clutter and affordable, high-speed, quick-reaction, terminally guided weapons. Advanced sensors with specialized high-speed signal processing, as well as new missile gun technology, will be required.

Air Superiority. Incremental improvements will be required in this area across a broad range of technologies. Advanced sensors and electronic devices will provide the pilot of the future with considerably improved situation awareness. Higher speed computers with dedicated signal processing will support a much improved human-system interface that will allow the pilot to focus attention on the most critical time-sensitive tasks. Finally, improved materials and propulsion will provide higher performance aircraft.

Netted Systems. The netting of today's autonomous systems to provide improved force level coordination and resource allocation will require significant advances in high-capacity, secure, LPI data links. It also will require specialized computers and signal processing to provide tailored displays and interfaces to operators at multiple levels.

3. Air Superiority and Defense: *Key Technology Areas*

TBM DEFENSE

1. Computers
2. Software
3. Sensors
4. Communications Networking
5. Electronic Devices
7. Materials and Processes
9. Propulsion and Energy Conversion
11. Human-System Interfaces

COUNTERSTEALTH

1. Computers
2. Software
3. Sensors
4. Communications Networking
5. Electronic Devices
9. Propulsion and Energy Conversion
11. Human-System Interfaces

SHORT-RANGE AIR DEFENSE

1. Computers
2. Software
3. Sensors
4. Communications Networking
5. Electronic Devices
9. Propulsion and Energy Conversion
11. Human-System Interfaces

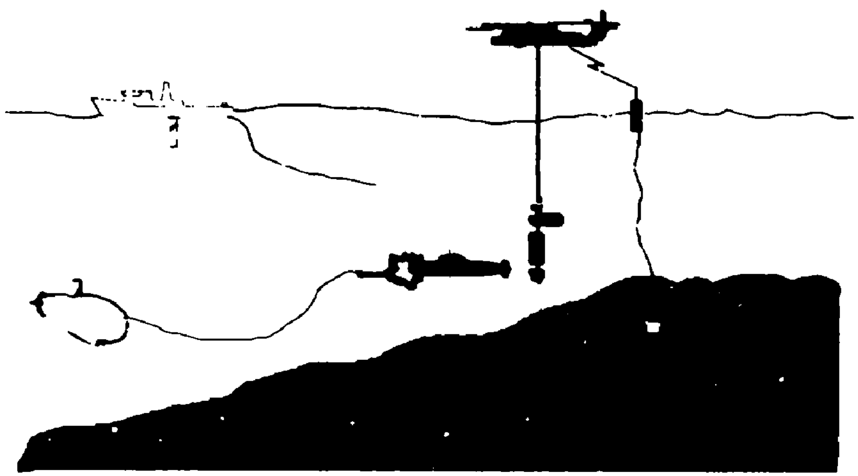
AIR SUPERIORITY

1. Computers
2. Software
3. Sensors
4. Communications Networking
5. Electronic Devices
7. Materials and Processes
9. Propulsion and Energy Conversion
11. Human-System Interfaces

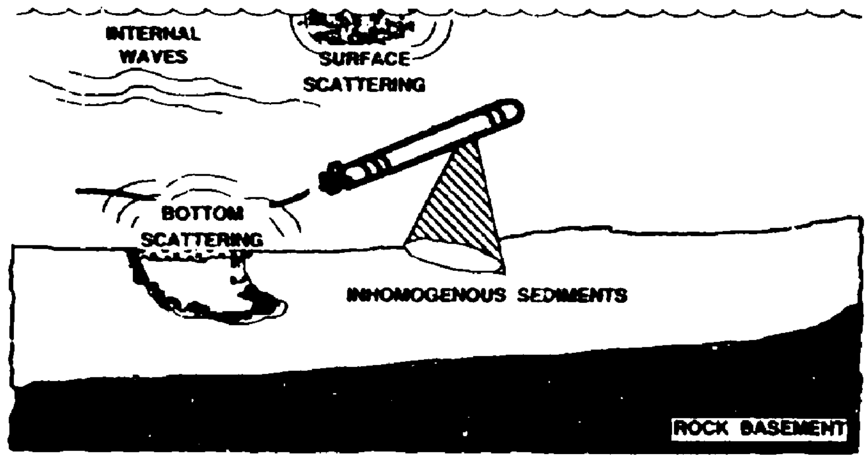
NETTED SYSTEMS

1. Computers
2. Software
3. Sensors
4. Communications Networking
5. Electronic Devices

SHALLOW WATER / REGIONAL CONFLICT

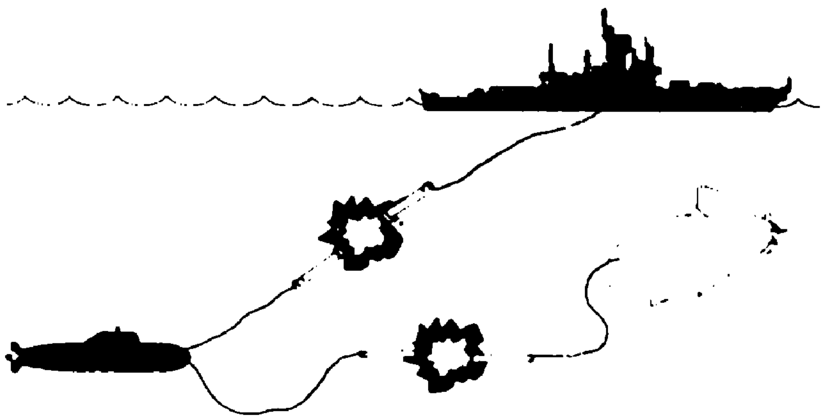


UNDERSEA TACTICAL MULTIPLIERS

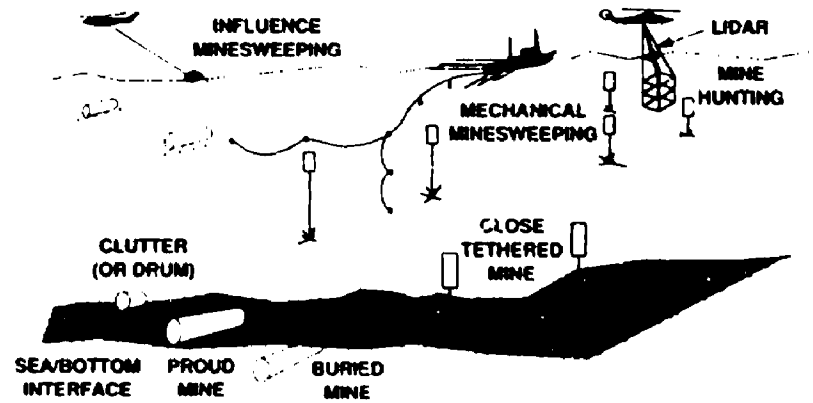


PLATFORM PROTECTION

TORPEDO DEFENSE



MINE COUNTERMEASURES



4. Sea Control and Undersea Superiority: *Legacy*

Background. This Thrust has been established to respond to the military requirements posed by the growing need for naval forces to operate in coastal areas. The challenge is to identify, develop, and demonstrate capabilities for distributed, fixed, and mobile platforms. These platforms are to be equipped with full spectrum sensors and improved communications, netted together for fire support, carrier strike, missile defense, anti-submarine warfare (ASW), and anti-mine warfare. In particular, it will develop a robust shallow water and regional conflict capability, which does not exist today, while maintaining an adequate technology base to counter deep water threats.

The requirement for connectivity between surface and subsurface units to efficiently control coastal areas for mine clearance, naval fire support, and amphibious landings necessitates the development of a cohesive set of advancements. Execution of the sea control strategy will enhance the capability to conduct amphibious operations and maintain strategic agility, using technological superiority to enhance the swift termination of conflict. This capability requires the ability to discriminate between and counter various threats, particularly those posed by missile patrol and small boats.

Shallow Water/Regional Conflict Naval Warfare Capability. As the importance of regional conflict increases, the Navy must be prepared to counter threats from coastal missiles and mines, as well as from small, low-target-strength submarines operating in highly cluttered, shallow coastal waters. Improved low frequency active systems, non-acoustic sensing systems, and advanced high-speed computational and data fusing techniques will be developed to provide our forces with robust shallow water systems. At the same time we will improve the capability of our naval weapons to operate successfully in the coastal environment.

Platform Protection/Point Defense. As the global threat continues to decline, the Navy will be composed of fewer ships and submarines, making each relatively more valuable than its present day counterpart. Enhanced platform protection through affordable signature control and point defense systems, effective against mines and torpedoes, is required to ensure the safety and viability of these forces. Programs leading to improved defense against missile and aircraft attack (see Thrust 3), torpedo hardkill systems for both surface ships and submarines, robust shallow water mine countermeasures, and improved shallow water submarine detection and kill capabilities all enhance platform protection and provide capabilities that do not exist today.

Tactical Multipliers. These systems bring forth technologies which serve as force multipliers and enhance the ability to operate successfully within a wide range of environmental and tactical conditions. As military systems grow more complex and sophisticated, the variability of the natural environment on their performance becomes increasingly significant. Tactical oceanography provides the on-scene commander with quantified graphic descriptions of the environment and its effects on warfighting systems. When fully implemented in operational networks, this capability will link all tactical units in an interactive net similar to SimNet. Rapid advances in computer technology and component miniaturization offer the potential for a number of attractive unmanned undersea and air vehicle options that would act as low cost force multipliers. Their potential stealth and covertness make them well suited for use in regional conflict scenarios.

4. Sea Control & Undersea Superiority: *Legacy*

Today	*2000-2005: Potential Via S&T*
Shift Emphasis From Open Ocean/ Blue Water Capabilities →	**Increase Regional, Shallow Water, Third World Focus**
• High capability in open ocean, but limited capability in littoral zones	• Robust shallow water/regional warfare capability - Detection/classification/localization sensors - Shallow water weapon upgrade
• Limited self-protection for ships and submarines	• Ample platform protection/point defense - Mine countermeasures - Torpedo defense - Affordable low signature platforms
• Limited capability in coastal regions; environment/locality a potential show-stopper	• Tactical multipliers - Environmental sensor systems - Unmanned undersea and air vehicles

4. Sea Control and Undersea Superiority: *Functions and Goals*

Goals. This Thrust comprises seven goals that, if fulfilled, would provide the greatest potential for meeting critical needs and that should receive priority for development. These goals can be expressed in terms of three essential warfighting functions.

Search/Target. Effective shallow water detection, classification, and localization of small, low-target-strength submarines and mines in relatively cluttered shallow water environments is essential if our forces are to meet the requirements of likely regional warfare conflicts. To achieve this end, acoustic and non-acoustic detection techniques—including advanced periscope detection methods—will be pursued. Tactical oceanography and the off-board sensor capability provided by unmanned undersea vehicles (UUVs) will act as enablers and force multipliers which enhance the capability of our forces to operate successfully in the harsh, shallow water environment. Information will be networked using enhanced communication techniques to enable the "hand off" of targeting data to improve battle group operations.

Attack/Kill. A robust shallow water torpedo and weapon capability is needed to ensure that our forces have the means to counter hostile undersea threats anywhere they are encountered. The shallow water environment poses severe challenges to achieving effective weapons performance.

Survive. To complete the picture, assured torpedo defense, effective in-stride shallow water/surf zone mine countermeasures, and reduced platform signatures all enhance the ability of our forces to survive in conflict. Platform survivability is best achieved by preventing detection by enemy sensors and, in the event of detection or attack, having the capability to neutralize enemy weapons.

4. Sea Control & Undersea Superiority: *Functions & Goals*

Functions	*Goals*
• Search/Target	• Effective shallow water detection, classification, and localization of submarines and mines • Networked tactical oceanography • Off-board/remote sensor capability
• Attack/Kill	• Robust shallow water torpedo and weapon capability
• Survive	• Assured torpedo defense • Effective shallow water/surf zone mine countermeasures • Reduced signatures

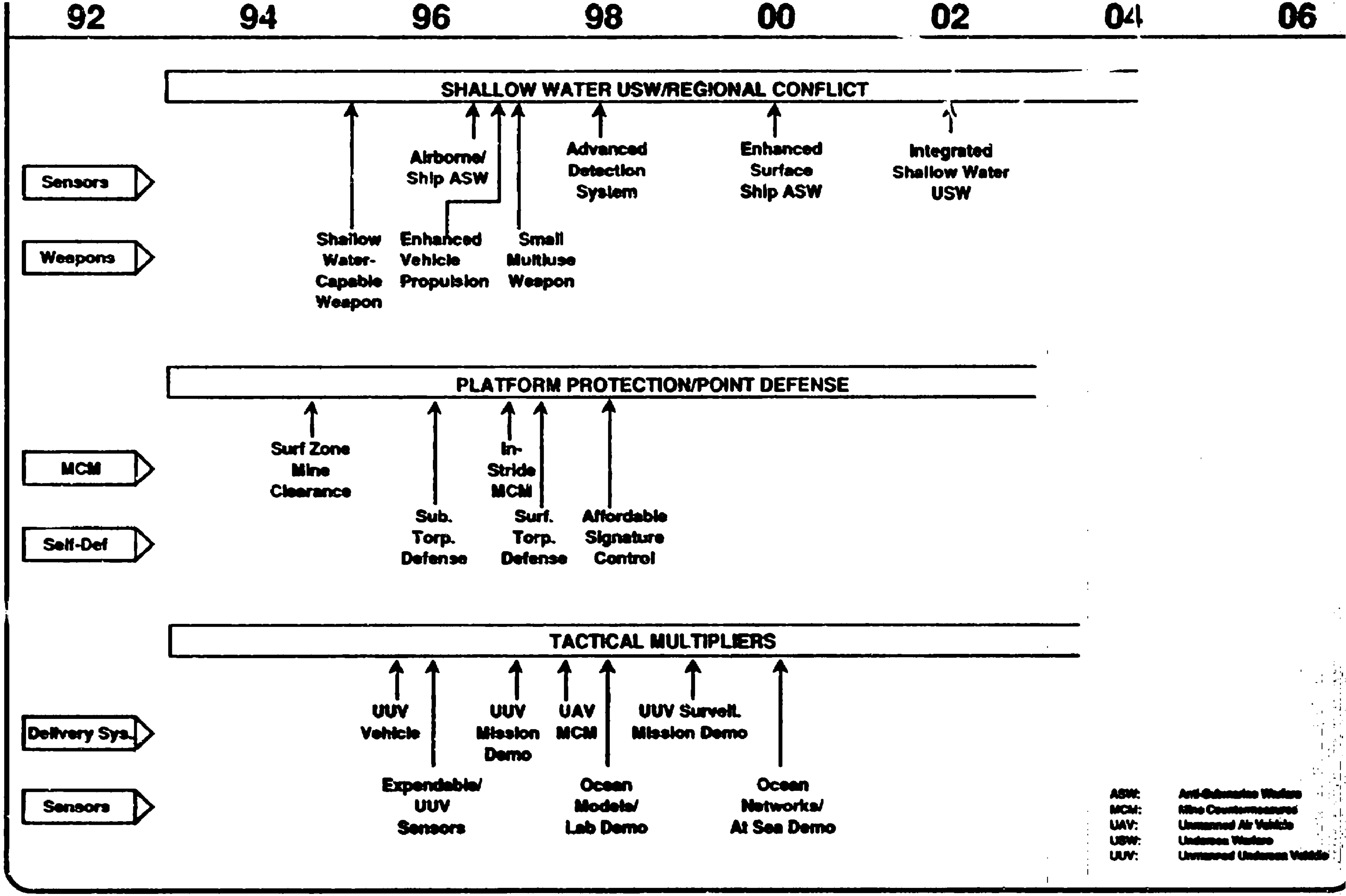
4. Sea Control and Undersea Superiority: *Top-Level Demonstrations*

The following technology demonstrations are important to achieving the goals established for this Thrust. The list is preliminary in nature, pending further refinements.

Shallow Water/Regional Conflict. Two major elements are being pursued in this area. *Sensor systems development* efforts will demonstrate improved full spectrum and active classification algorithms in the near term. In the longer term, these efforts will produce a robust shallow water submarine detection and targeting capability consisting of integrated acoustic and non-acoustic detection systems networked with advanced laser communications and high performance computers. The second element provides a *robust shallow water ASW weapon capability*. At-sea demonstrations of technology required for upgrading present torpedoes to achieve full performance capability in harsh, shallow water environments will be completed in the near term. In the mid to far term, the technologies required for a small, lower cost ASW weapon for use in regional conflicts will be demonstrated.

Platform Protection/Point Defense. The focus here is on the protection of both submarines and surface ships from attack by torpedoes and mines. The milestones are relatively near term because of the urgency for achieving an improved capability. Demonstrations through in-water testing of technology for all elements of a ship defense system—detection sonars and algorithms, combat control, launcher, hardkill countermeasures—will be pursued.

Tactical Multipliers. Tactical oceanography will demonstrate integrated environmental tactical displays and decision aids for use by local commanders. The capability to provide real-time updates of the environment and its impact on system performance by fusion of *in situ* data and ocean models will be demonstrated. Unmanned undersea vehicle demonstrations will result in technologies leading to a vehicle with covert environmental sensing and improved long-range propulsion capabilities. Unmanned air vehicle (UAV) demonstrations will lead to covert over-the-horizon sensing capabilities.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SHALLOW WATER USW/REGIONAL CONFLICT
Sensors
Weapons
Airborne/ Ship ASW
Advanced Detection System
Enhanced Surface Ship ASW
Integrated Shallow Water USW
Shallow Water-Capable Weapon
Enhanced Vehicle Propulsion
Small Multiuse Weapon
PLATFORM PROTECTION/POINT DEFENSE
MCM
Self-Def
Surf Zone Mine Clearance
In-Stride MCM
Sub. Torp. Defense
Surf. Torp. Defense
Affordable Signature Control
TACTICAL MULTIPLIERS
Delivery Sys.
Sensors
UUV Vehicle
UUV Mission Demo
UAV MCM
UUV Surveil. Mission Demo
Expendable/ UUV Sensors
Ocean Models/ Lab Demo
Ocean Networks/ At Sea Demo
ASW: Anti-Submarine Warfare
MCM: Mine Countermeasures
UAV: Unmanned Air Vehicle
USW: Undersea Warfare
UUV: Unmanned Undersea Vehicle

4. Sea Control and Undersea Superiority: *Key Technology Areas*

A number of Key Technology Areas are essential to the achievement of successful demonstrations in each of the related areas.

Shallow Water/Regional Conflict. The surveillance of small, low-target-strength submarines in shallow water is a complex problem. Success is dependent on advanced full spectrum signal processing, robust active classification algorithms, non-acoustic sensors, low-cost and reliable low-frequency active sources, and artificial intelligence. High-performance computers, sensors, and software are prime examples of important technologies that will be employed to achieve the goals.

Achieving effective torpedo performance in shallow water requires advanced guidance and control technology for autonomous detection and classification of targets in a high-reverberation, dense false-target environment. For air-delivered weapon applications, techniques to permit weapon launch into very shallow water without hitting the bottom are needed. The feasibility of small, lower cost weapons for the future depends upon the development of advanced warhead, propulsion, and silencing technologies.

Platform Protection/Point Defense. The first step in platform protection is to make the platform undetectable. Advanced signature reduction techniques for submarines and ships are necessary to ensure platform survivability in shallow water. Technologies essential to enable this are improved, affordable quieting of radiated acoustic noise, active acoustic and magnetic signature control, and reduced target strength against active threats.

The second step is to neutralize a threat weapon system before it can be launched. Systems to first localize and then map and destroy mines are the principal focus. Technologies essential for mine clearance include improved explosives configured into large arrays and sophisticated rocket systems for deployment. Mine hunter/killer weapon technologies require acoustic, magnetic, and electro-optic sensors for the detection and classification of mines and shallow water remote platforms. They also need accurate guidance and control for placement, high-endurance miniature propulsion systems, and high-energy-density warhead technologies for neutralization.

The final protective action is to divert or destroy threat weapons once they have been launched. The point defense of surface ships and submarines against torpedo attack requires advanced techniques to rapidly detect, classify, and localize an incoming torpedo for initial alert and to provide critical data for countermeasure response. Countermeasures to achieve an impenetrable layered defense, including a novel hardkill component, rely heavily on sensor, computer, and software technologies for guidance and control, propulsion, and warheads.

Tactical Multipliers. An effective shallow water capability requires accurate and timely knowledge of the natural environment and its impact on systems performance (environmental effects). Software and other technologies to develop low-cost environmental sensors and to integrate them with advanced ocean/atmosphere computational models and systems simulations are essential.

Unmanned undersea and air vehicles will require robust, reliable mission controllers, based on artificial intelligence and other advanced computational techniques; energy-dense, long-endurance power supplies; and integrated suites of acoustic and non-acoustic sensors for surveillance and environmental sensing purposes.

SHALLOW WATER UNDERSEA WARFARE/REGIONAL CONFLICT

1. Computers
2. Software
3. Sensors
4. Communications Networking
5. Electronic Devices
6. Environmental Effects
8. Energy Storage
9. Propulsion and Energy Conversion
11. Human-System Interfaces

PLATFORM PROTECTION/POINT DEFENSE

1. Computers
2. Software
3. Sensors
4. Communications Networking
5. Electronic Devices
6. Environmental Effects
7. Materials and Processes
8. Energy Storage
9. Propulsion and Energy Conversion
10. Design Automation
11. Human-System Interfaces

UNDERSEA TACTICAL MULTIPLIERS

1. Computers
2. Software
3. Sensors
4. Communications Networking
5. Electronic Devices
6. Environmental Effects
7. Materials and Processes
8. Energy Storage
9. Propulsion and Energy Conversion
10. Design Automation
11. Human-System Interfaces

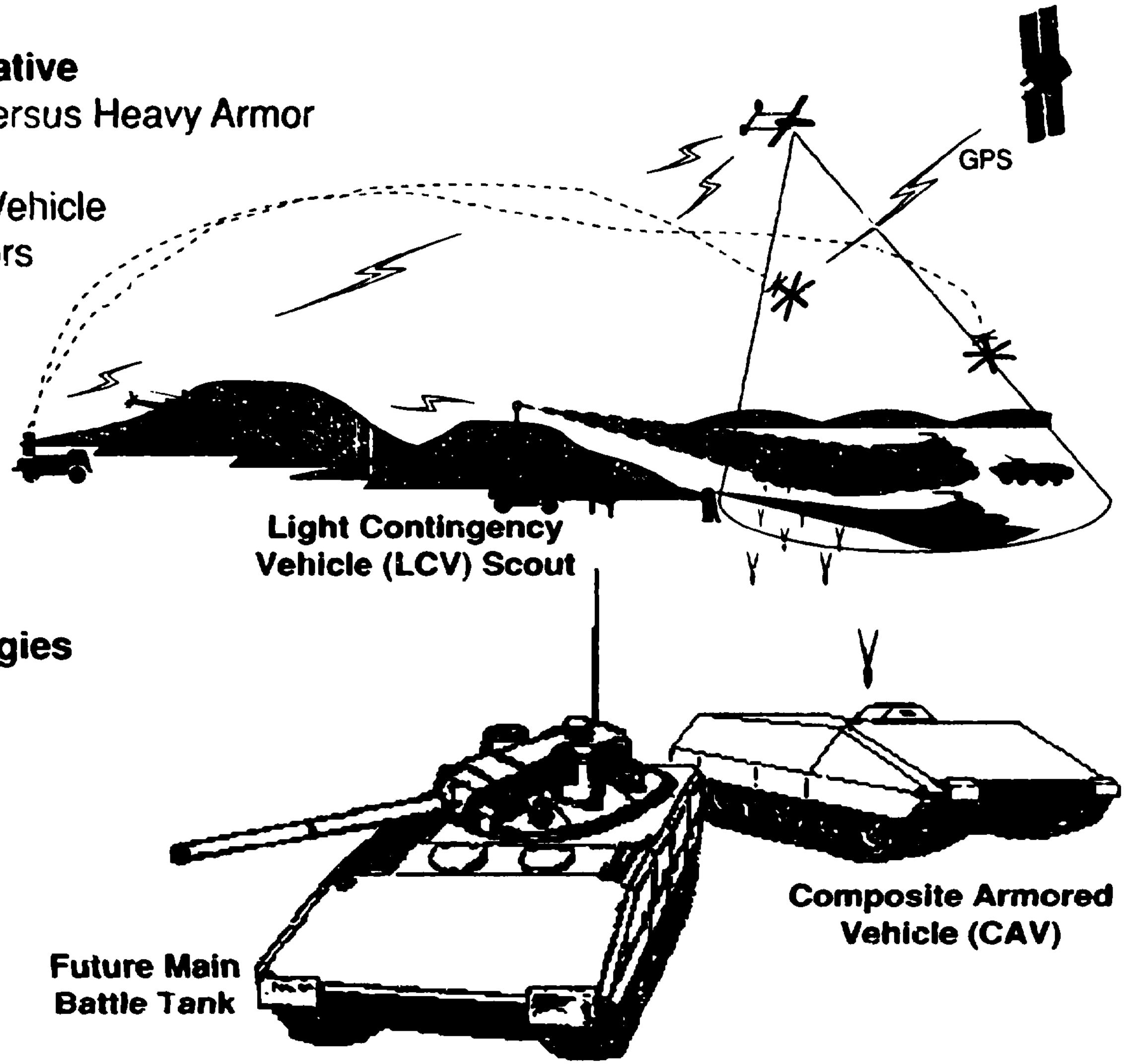
5. Advanced Land Combat

Rapid Force Projection Initiative
Army Airborne/First to Fight versus Heavy Armor
Standoff Attack
- High Survivability Scout Vehicle
- Scout and Robotic Sensors
- NLOS Missiles/Weapons
- GPS Connectivity

Legacy:
More Capable
"Lethal Light" Forces

Advanced Vehicle Technologies
Composite Structures
Integraied Survivability
Reduced Crew

Legacy:
More Deploy̷able
(Lighter) "Heavy" Forces



5. Advanced Land Combat: *Legacy*

BACKGROUND

Recent experiences in Operations Urgent Fury, Just Cause, and Desert Storm demonstrated the need for the rapid deployment and insertion of light forces that will be the "first-to-fight." In dealing with regional conflicts, the prepositioning of equipment is less practical than it was in Europe. Operation Desert Storm exposed the vulnerability of our "first-to-arrive," lightly equipped contingency forces (airborne, in the case of the Army) to Third World threats equipped with heavy armor.

Our heavy forces, while survivable and lethal, have become heavy and large, and thus difficult to transport, even by land or sea. The employment of continually greater weights of armor has been used to fend off ever-increasing levels of threat, but the larger, heavier, more lethal systems have required more powerful engines, more fuel, and more ammunition—all cycles and trends that must be corrected to improve deployability.

FUTURE

All elements of the future advanced land combat force must be highly deployable, able to execute missions outside the operational envelope of opposing forces, and survivable against a myriad of lethal anti-armor weapons.

Rapid Force Projection Initiative. This initiative will demonstrate the technologies for an air-droppable system that fuses the capabilities of lightly armored stealthy vehicles, advanced sensors, and stand-off weapons. Using electro-optics and smart weapons, it will minimize the vulnerabilities of lightly armored vehicles by providing them with the capability to kill the enemy before it can close to direct fire ranges. It exploits new hunter/killer and barrier concepts to provide the most "punch per pound."

Lighter "Heavy" Forces. Today's investments will allow future forces to deploy within the constraints imposed by the worldwide transportation infrastructure. Advanced materials and designs, coupled with innovative tactical concepts and reduced crew size, will yield large vehicle weight reductions. Improvements in fuel and ammunition efficiency, combined with more reliable vehicle systems, will significantly reduce the required support package for deployed units. Light component forces will be more capable; heavy component forces will be more deployable.

Integrated Survivability. Future land combat forces will be hard to detect, hard to hit if detected, and survivable if hit. They will no longer rely mainly on greater armor weights for survivability. Integrated systems of active and passive signature control and obscuration, threat warning sensors, active countermeasures, and extremely light-weight armor will provide revolutionary increases in survivability and improved deployability.

See, IFF, Shoot, and Kill First. Future soldiers will be able to see and hit farther and faster than the opposing threat in all environmental and battlefield obscurant conditions. Positive, non-exploitable identification friend or foe (IFF) will ensure that extended range weapons can be used without endangering our own troops. Advanced sensors and countermeasures will create a battlefield opaque to our opponent but clear to friendly forces, where extended range weapons can be used to maximum effect.

Battlefield Management On the Move. Advanced C3I architectures and sensor/intelligence-sharing technologies will give unit commanders a real-time basis for tactical decisions. Minimizing idle assets, lost units, and target overkill will improve unit combat efficiency enormously. Shared situation awareness will enable small forces to outwit, outfight, and outmaneuver larger opponents. The goal is rapid, lightning fast engagements that quickly destroy the enemy's will and capability to fight.

5. Advanced Land Combat: *Legacy*

Today	*2000-2005: Potential Via S&T*
• Light forces are deployable, but vulnerable vs. heavy forces	• Rapid Force Projection Initiative - Air deployable/air droppable - Lethal - Survivable vs. armored threat - Not dependent on prepositioning
• Heavy forces are capable, but: - Too long to get there - Not easily deployable - Long logistic tail	• Lighter "heavy" forces - Sea deployable in half the time with half the ships - Overwhelming lethality - Survivable - Operate without road restrictions
• Survival is reliant upon heavy armor	• Integrated survivability systems
• Detect/kill ranges comparable to potential threat forces	• See, IFF, shoot, kill at extended ranges
• Voice radio, paper maps, grease pencils	• Burst transmissions, electronic maps/automated crew functions, situational awareness/intelligent decision aids

5. Advanced Land Combat: *Functions and Goals*

The primary goal of the future advanced land combat force is to exploit advanced technologies to ensure the rapid projection of forces to defend, deny, and overwhelm enemy forces, anywhere, at any time.

Goals for the future force were constructed to achieve the future strategic power projection of overwhelming force—globally, rapidly, and against diverse adversary forces. This will occur through synergistic improvements in the traditional combat functions—move, shoot, communicate, and survive—coupled with major transportability improvements.

Future advanced land combat systems will be characterized by tremendous tactical mobility, thus permitting the rapid concentration of force. Increased lethality at increased ranges will allow U.S. forces to see, shoot, and kill before an enemy can respond effectively. Crew workloads will be reduced through automation, simplification, and improved information flow and management to achieve real-time battle management. Optimizing the mix of non-traditional survivability strategies (e.g., signature management and active countermeasures) will improve survivability against the proliferation of "smart" weapons.

The emphasis will be on exploring new hunter/killer and barrier concepts to provide more punch per pound. The goal is to use standoff weapons to establish a killing zone beyond the engagement range of the enemy, so that enemy heavy tanks cannot close with our more vulnerable light forces. This new technology for the light forces will complement the man-portable anti-tank weapon (Javelin) and advanced, self-deployable scout/attack rotorcraft (Comanche) systems, which are already in development.

Included in the advanced land combat effort are two projects that support all weight classes. The Integrated Survivability program is developing threat warning sensors and countermeasures. The Crewmember's Associate project will reduce crew size and increase crew effectiveness by providing better communications and situational awareness.

The net effect of meeting these goals simultaneously will be to provide all categories of combat vehicles—heavy, medium, and light—with substantially reduced gross vehicle weight. Even more important will be their marked reduction in vulnerability as a result of unconventional survivability technologies and greater accuracy and lethality (towards the goal of one shot/one kill). More reliable and durable systems, subsystems, devices, and parts will contribute through greatly increased reliability and sustainability. The transportability payoff will come from meeting the goal of deployment in half the time and sustainment with half the ships, as well as substantial improvements in air drop capability.

Goals for combat vehicles were constructed in the four major combat functions of lethality, survivability, mobility, and communications, plus transportability. These goals were derived via "requirements pull" as articulated by the operational users. The goals were translated into technology objectives within the areas of move, shoot, communicate, survive, and support.

Advanced land combat, of course, includes other elements not covered here, including advanced (electric and non-line-of-sight) guns, line-of-sight (LOS) missiles, rotorcraft, countermines, and artillery.

5. Advanced Land Combat: *Functions & Goals*

Functions	*Goals*
• Transportability	• Rapid Force Projection Initiative - Air droppable, air liftable (< 16 tons) - Medium forces—air transportable (~22 tons) - Heavy forces—reduce surface transportation limits (~40 tons)
• Lethality	• Identify and kill beyond conventional cannon range
• Survivability	• Reduced signature Integrated survivability Embedded identification friend or foe (IFF)
• Communications	• Integrated automated crew stations Improved decision making and coordination through battlefield management and combined arms situational awareness
• Mobility	• Increased on- and off-road speed capability

5. Advanced Land Combat: *Top-Level Demonstrations*

ADVANCED VEHICLE TECHNOLOGY

Integrated Survivability

1st Generation: Integration of signature reduction, light armor, threat sensors, and countermeasures.

2nd Generation: Hit and kill avoidance systems, including active defense focusing on improved capabilities with reduced weight and power burdens.

Command and Control

Combat Vehicle/Combat Arms Command and Control: Enhanced situational awareness and communications between combined arms.

Crewman's Associate: Integrated/automated crew stations for more effective, smaller crews.

Target Acquisition: Infrared (IR) and radar target acquisition with aided target recognition for semi-automatic search.

Composite Armored Vehicle (CAV)

CAV ATD: Medium weight-class platform with structure/armor made of composite materials. Emphasis is on manufacturability, durability, and utility of structures to enable lighter weight, reduced signatures, and enhanced force projection.

Future Main Battle Tank (FMBT)

FMBT ATD: Demonstration of advanced target acquisition, two man crew, and integrated protection on an existing chassis, with extensive user test, to assess the feasibility and practicality of a significantly lighter FMBT.

RAPID FORCE PROJECTION INITIATIVE

Light Contingency Vehicles

Light Contingency Vehicle (LCV): Air droppable, air liftable (16-ton maximum), survivable, reduced signature, scout vehicle platform, with advanced situation awareness.

Sensors

Target Acquisition/Positioning Demo: Second generation forward-looking IR radar (FLIR), laser rangefinder/designator, and global positioning system (GPS) integrated on LCV.

Remotely Piloted Vehicle (RPV) Target Acquisition/Robotic Sentry: Low cost, integrated sensor suites with remote operation.

Multi-Mode Non-Line-of-Sight Stand-off Weapons

Missile Demonstration: Remotely directed missile system, such as FOG-M modified with GPS and IR seekers, high mobility artillery rocket system (HIMARS) with upgraded submunitions, and other ground-launched NLOS weapons, such as TACAWS (The Army Combined Arms Weapon System) and Longbow, to engage armor beyond enemy direct fire range.

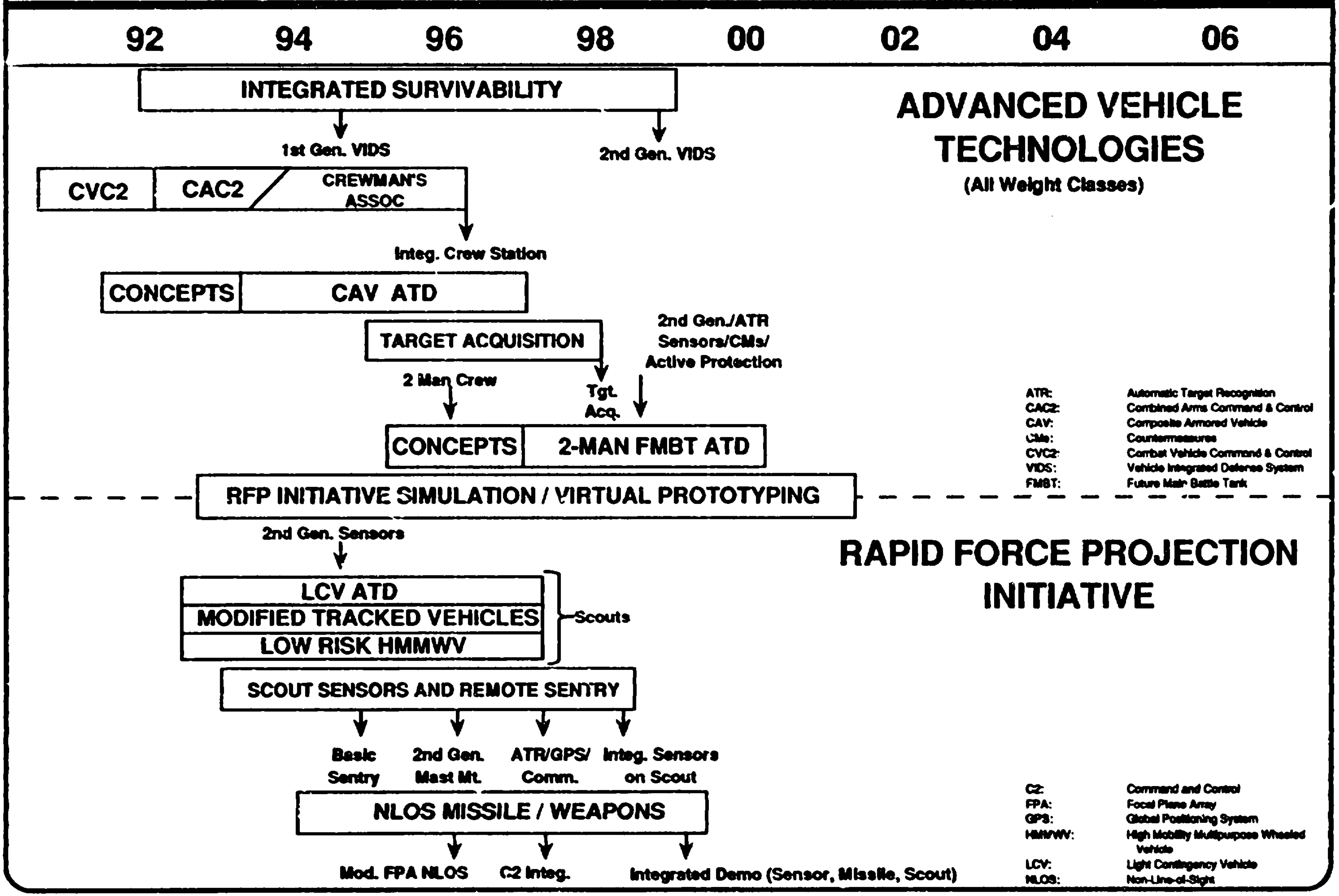
Smart Weapons: NDI (non-developmental item) smart mortars and mines with command links.

Rapid Force Projection Initiative Demonstration

Integrated Demonstration: Sensors, missiles, weapons and scout working together with user participation in field environment. Scouts will include LCV, modified track vehicle, and HMMWV.

Virtual Prototyping: *Distributed Simulation*. Virtual prototyping with diverse distributed simulation capabilities will allow numerous design excursions of advanced land combat technologies on the synthetic battlefield before committing to hardware. Simulation will be used to identify and validate the most advantageous mix of advanced technologies for making light forces survivable within weight limits.

5. Advanced Land Combat: *Top-Level Demos*



5. Advanced Land Combat: *Key Technology Areas*

To achieve the goals of (1) providing the first-to-fight, light forces with survivability and lethality against heavier forces, and (2) lighter heavy forces to dramatically increase deployability, several advances are required. The advances with the largest impact are those that enable a reduction in crew size, armor, and structural weight, improved signature management, and remote sensing and targeting.

1. **Computers.** The rapid integration and processing of information from a wide variety of sources is critical to virtually all functions in the future land combat force. These include command and control for more efficient battle management, the reduction of crew workloads for reduced crew size, and the fusion of sensor information for remote targeting and guidance, signature management, and countermeasure response.

2. **Software.** Simulations of battle management, signature control, and crew functions are needed, as are sophisticated algorithms for reducing crew workloads.

3. **Sensors.** Advanced sensors and signal processors play a vital role in this Thrust. Fuzed and/or multi-mode sensors are needed for target acquisition, fire control, threat sensing, and background measurements for active signature management

4. **Communications Networking.** Remote sensing and targeting for the hunter-killer concept will require continuous, secure communications between two vehicles. This necessitates a high bandwidth, low probability of intercept system. Effective reductions in crew size require greater situational awareness and improved command and control, for which higher capacity and more reliable communications systems are needed.

5. **Electronic Devices.** Components are needed for high resolution optical systems, improved displays, and active control of visible signatures. Devices for improved signal and information processing also are needed.

6. **Environmental Effects.** The influence of the environment on sensors, target acquisition systems, and visibility must be considered to attain capabilities to out-see, out-shoot, and out-maneuver the enemy.

7. **Materials and Processes.** Lightweight composite structures are critical to the weight reduction of armored vehicles. Thick-section composites for vehicle structures need better characterization, and the issues of repairability, non-destructive testing, and affordable manufacturing need to be carefully addressed. Techniques for integrating signature control into composite structures are particularly challenging, and will involve new methods for fastening and joining. The material technology associated with reduced signatures is particularly critical.

8. **Energy Storage.** Higher energy density warheads will contribute to weight reduction, while maintaining lethality.

9. **Propulsion and Energy Conversion.** To meet the weight reduction goals for future armored vehicles, higher power density and more efficient powerplants are required.

10. **Design Automation.** A closely coupled suite of models is needed to provide vehicle designs with maximum military utility, while ensuring manufacturability and minimizing development cost and time.

11. **Human-System Interfaces.** An important way to reduce a vehicle's weight and size is to reduce its crew size. For this to occur, crew functions must be augmented by intelligent decision aids and the associated fusion and display of information.

5. Advanced Land Combat: *Key Technology Areas*

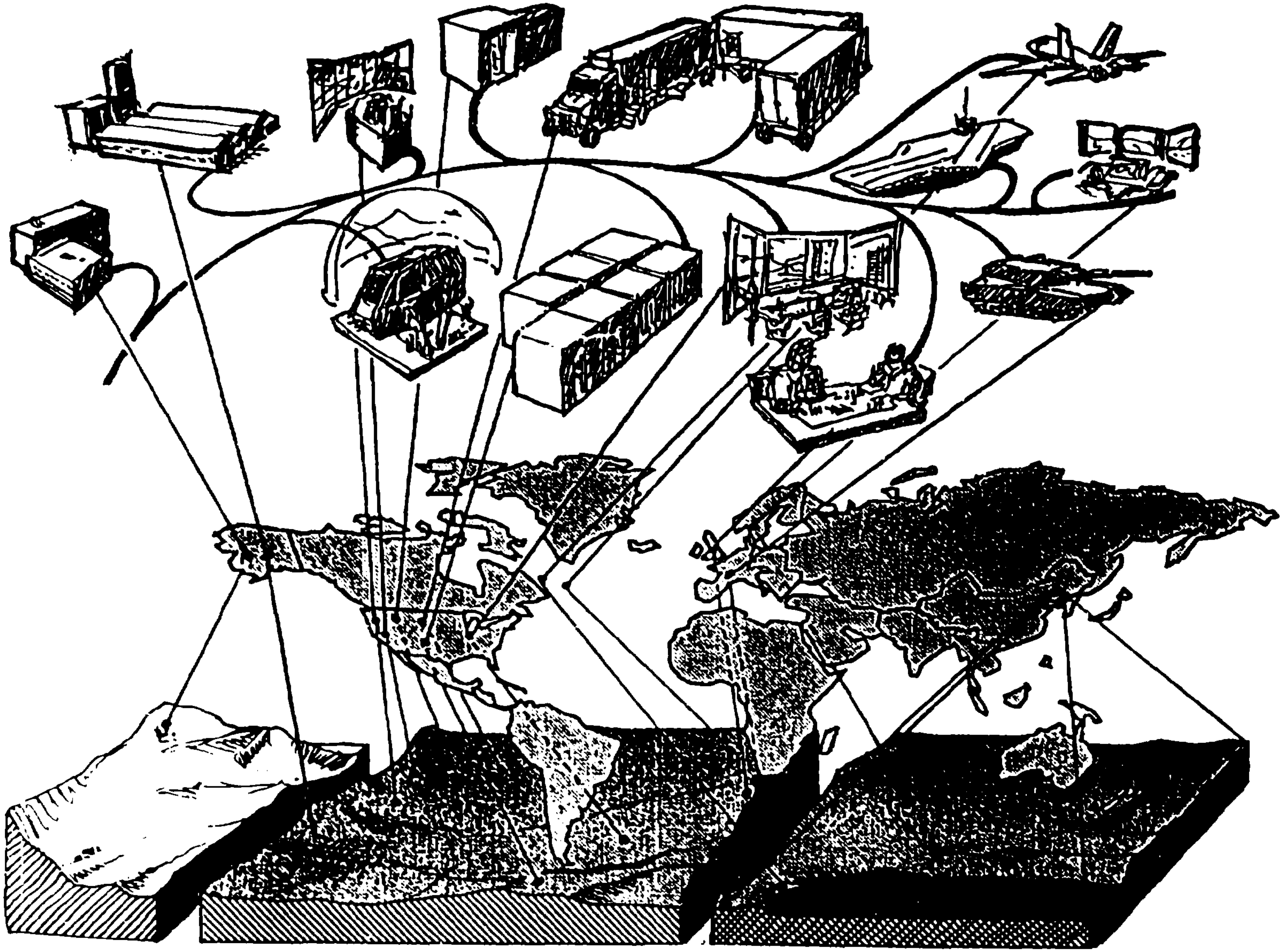
ADVANCED VEHICLE TECHNOLOGIES

1. Computers
2. Software
3. Sensors
4. Communications Networking
5. Electronic Devices
6. Environmental Effects
7. Materials and Processes
9. Propulsion and Energy Conversion
10. Design Automation
11. Human-System Interfaces

RAPID FORCE PROJECTION INITIATIVE

3. Sensors
4. Communications Networking
5. Electronic Devices
6. Environmental Effects
7. Materials and Processes
8. Energy Storage
9. Propulsion and Energy Conversion
10. Design Automation

6. Synthetic Environments



6. Synthetic Environments: *Legacy*

This Thrust will deliver as its legacy the ability to routinely construct, on demand, a robust variety of synthetic environments that will enable fundamental changes in how mainline defense functions are accomplished in the 2000s.

Synthetic environments are internetted simulations that represent activities at a high level of realism, from simulations of theaters of war to factories and manufacturing processes. These environments are fundamentally different from the traditional simulations and models known today. They are created by confederations of computers, connected by local and wide area networks and augmented by superrealistic special effects and accurate behavioral models. They allow complete visualization of and total immersion into the environment being simulated.

Any defense system that has a computer will ultimately be able to interoperate within these environments: combat platforms, C2 and C3 systems, netted simulations, models and wargames, etc. This mix and match of systems will appear seamless to users. Internets of successful simulations will evolve into next generation C3 systems.

The capability will exist to fabricate synthetic environments on demand and to tailor them for specific defense uses. These environments will come in many shapes and sizes; will replicate real-world locations precisely; will represent past, current, or future conditions; will be used locally or netted across multiple users for very large operations; and will use the same databases as other applications within defense.

Backbone networking will allow many environments to exist simultaneously without interference. Battlefields will be in existence 24 hours a day, and forces will be "fighting" year round.

Training and Readiness. Frequent and intensive access to synthetic battlefields will allow the joint force commander to exercise his forces along the full range of weapon systems, doctrine, tactics, techniques, and organizations against professional, sentient opponents. All aspects of the combat force, combat support, and combat services support will be exercised. Mastery of warfighting skills will result as every team member becomes a veteran of scores of hard fought expeditions.

Joint Doctrine. Doctrine is institutionalized in a force through "doing." Outside of actual combat, the only place for large joint forces to practice and master joint doctrine will be on synthetic battlefields. This is where the unique style of U.S. warfighting will be learned, refined, and mastered in the 2000s.

Requirements Definition. Studying concepts on a hostile battlefield manned by warfighters focuses the requirements process. Having access to these battlefields also educates and enlightens those in industry and academia with innovative ideas. This should sharpen and clarify the definition and understanding of requirements for new or upgraded systems.

Design, Prototyping, and Manufacturing. The attributes and impacts of systems will be rapidly changed and studied on the battlefield. Virtual prototypes will be produced, and design and manufacturing tradeoffs evaluated. The first manufactured unit will be the "B Model," incorporating lessons learned on the synthetic manufacture of a synthetic A Model.

Contingency Planning, Operations, After Mission Review, and Historical Analysis. Future systems will have embedded connections into synthetic environments. Techniques perfected in simulations will be taken to war. Deployed units will be netted into the simulation infrastructure. Should circumstances permit, realistic training and dress rehearsals can continue using the virtual support of the internet. The same tools used in simulations, such as the Electronic Sand Table, become mission planning tools in combat. The same tools used for data capture in simulations become mission review and historical analysis tools in combat. The distinction between computer-based synthetic environments and computer-based operational systems blurs in the 2000s.

6. Synthetic Environments: *Legacy*

Today	*2000-2005: Potential Via S&T*
Separate Costly Stovepipes for Development, Acquisition, Test & Evaluation, Training, Intelligence, and Warfighting	**Pervasive Seamless Environment for Defense** **NEED → IDEA → FACTORY → BATTLEFIELD CONNECTIVITY** • Requirements forged in the heat of battle by warfighter/developer/industry team – RFPs are a slice of a living battlefield • Manufacturing bugs eliminated in synthetic factory before metal bending – "Get it right the first time" – C3 for the factory floor • Mastery of warfighting via round-the-clock combat – Every man and woman a "Top Gun," from soldier to CINC – Every team world class • Environments go to war—embedded connectivity in every defense system • The net becomes the C3 system

6. Synthetic Environments: *Functions and Goals*

The work in synthetic environments will provide the tools and standards to create environments of increasing size, complexity, and utility and the mechanisms for entering these environments. It also will provide the infrastructure for others to learn quickly how to construct their own environments.

Multipurpose Environments. Small experimental environments have been constructed to date, both of battlefields (e.g., the SimNet program) and of factories (e.g., at Stanford University). These will be substantially increased in scale. Ultimately, any worldwide location, as well as the most sophisticated manufacturing plants, could be captured and reconstructed as a synthetic environment. The same technologies construct both, thus they will converge into a single seamless environment.

Entry Mechanisms. To date, the mechanism for warfighters, designers, developers, testers, and others to enter synthetic battlefields has been through netted simulators, C2 and C3 workstations and, to a limited extent, actual equipment. This will be greatly expanded in the 1990s to include all defense systems that have networkable computers, including real combat platforms. Synthetic battlefields will be mixes of real ranges, virtual simulations, and aggregated constructions (e.g., wargame representations). Multipurpose surrogates, like semi-automated forces via computer emulation, will allow humans to be swapped in and out of battles for maximum effectiveness (no soldier to be a training aid).

Until now, the entry onto factory floors has been through the "magic window" of the graphics workstation. In the 1990s, total immersion into the factory will be possible through the same mechanisms that allow an individual soldier to immerse himself in the synthetic battlefield, including, for example, the sensors and displays of virtual reality technology.

Connectivity. Entry mechanisms will be connected by a global simulation internet that will support scores of simultaneous yet non-interfering environments. Intelligent gateways and fully distributed computing architectures will allow highly complex, interactive environments to exist with substantially less digital bandwidth than is required by conventional systems.

This connectivity will be embedded in future weapons systems so that as forces deploy to a crisis they will remain connected to the internetted infrastructure—they will take the infrastructure to war. They will be supported in readiness and dress rehearsals, operations, logistics, etc., over the network just as they were during peacetime. Nothing changes as they convert from daily warfighting in a synthetic environment to real battle. Even displays, such as the Electronic Sand Table, will be the same. The internet becomes a C3 system.

Through connectivity, the same techniques for recording and storing events in the synthetic battlefield will be applied to combat for rapid after-action review and later historical analysis. Through the infrastructure, battlefield events can be studied by the support structure outside the combat zone for modifications to tactics, doctrine, equipment, and so on.

Functions	*Goals*
Multipurpose Environments	• Any worldwide location • Any size, shape, detail • Present, past, future conditions • Variable resolution and granularity • Dynamic, living • Total immersion
Entry Mechanisms	• Entry into the synthetic environment via: - Instrumented real systems (e.g., combat platform) - C2/C3 stations - Netted simulators - Constructive models - Online simulations of manufacturing
Connectivity	• Worldwide internet connects entry mechanisms - Brings people and teams together in real time - Deploys to war - Virtual support

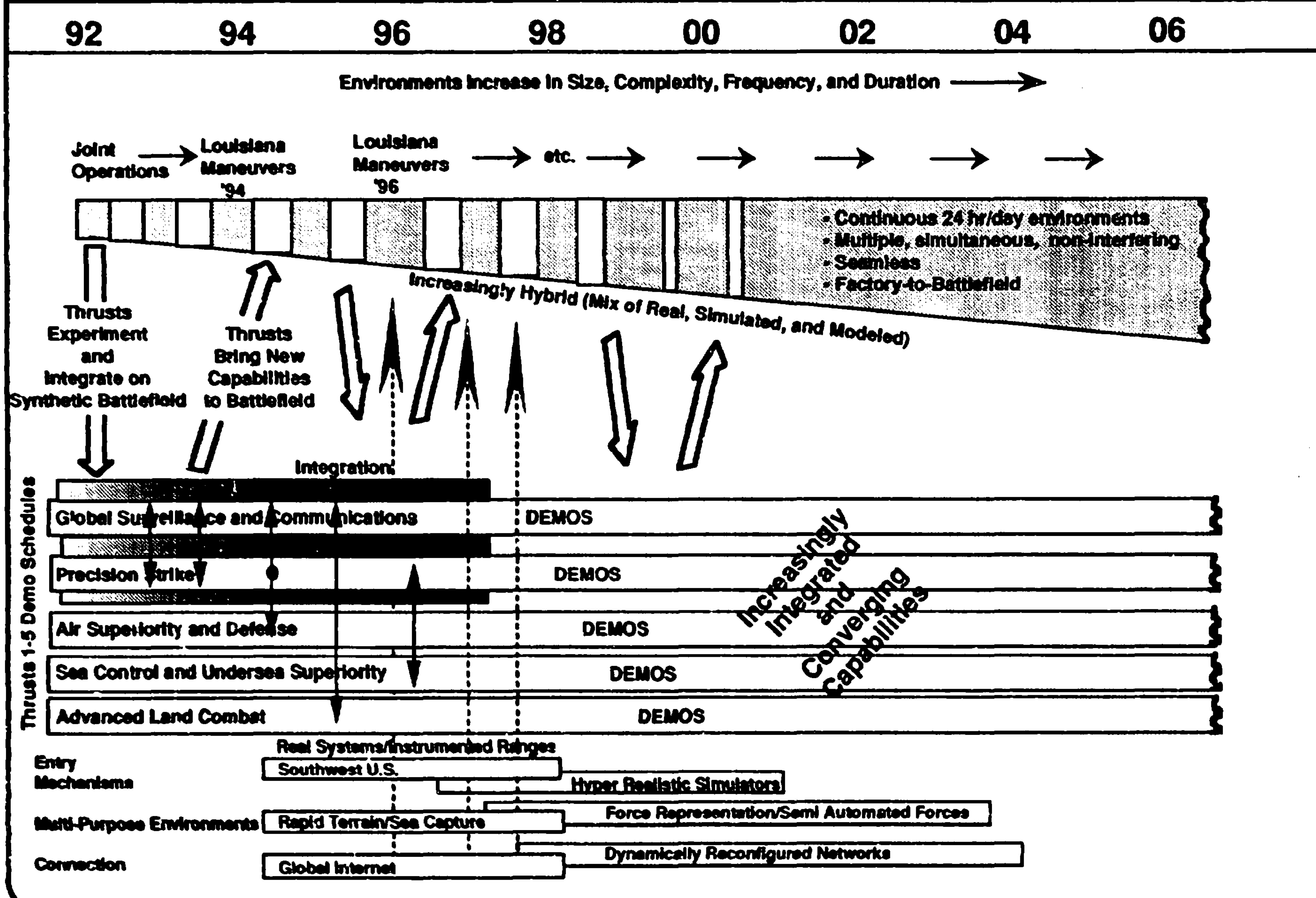
6. Synthetic Environments: *Top-Level Demonstrations*

Synthetic/Electronic Battlefield. The vision for this Thrust requires the creation of a synthetic environment; specifically, a synthetic or electronic battlefield. The battlefield will integrate representations of the forces of all relevant DoD components (and those of our allies)—it will have a "joint" orientation by design. The representations will include simulators, models, and wargames, as well as instrumented equipment and ranges. The outputs will be a seamless integration of interactive warfighting representations, many involving man-in-the-loop simulations and wargames, but many others based on validated or certified models of warfighting behaviors, including semi-automated forces (SAFORs). The technology will be used primarily for acquisition and for training and readiness.

Acquisition. The acquisition uses will include proposed weapon system simulations for concept definition and requirements validation, analysis to establish design parameters, and evaluations coupled with live demonstrations to validate theoretical models.

Training and Readiness. The training and readiness uses will include the collective training of military units in general warfighting skills, as well as their specific training for (real or potential) combat and doctrine. In certain planned developments it will provide for situational awareness and mission rehearsal in (real or potential) warfighting environments.

6. Synthetic Environments: *Top-Level Demonstrations*



6. Synthetic Environments: *Key Technology Areas*

Synthetic environments are created by sophisticated interactions between information systems that follow community-derived and -accepted standards and protocols.

The principal challenges include creating environments that are meaningful and realistic to human participants; having computers accurately represent human behavior, both individual and collective, when some humans are not present and must be represented by computers; creating environments that accurately describe real-world places; and connecting globally located sites economically through the dynamic allocation of bandwidth and connectivity, based on the interaction of elements within the environment being simulated (e.g., positions on the battlefield)

Synthetic Electronic Battlefields. Real-world locations must be sensed and characterized accurately and quickly if the location is of special interest. Large data-bases must be compressed efficiently. Distributed architectures disperse copies of these data bases to all elements on the network, and these databases must be stored in a form that enables rapid retrieval during the real-time rendering of scenes. The interoperation of multiple descriptions of the same environment—stored at different levels of detail for different users who interact within the environment at the same time—needs to be better understood.

Entry Mechanisms. There need to be many ways to enter synthetic environments, and these entry ports need to realistically represent the working environment of the users manning them. These could be instrumented combat platforms or work stations that abstract the essential characteristics of the platform. Since very large numbers of participants will ultimately be involved, a key technical challenge is to keep the cost of these devices as low as possible.

Connectivity. Very large internets that connect the widely diverse confederations of entry mechanisms need to operate within existing or planned communications systems. The clever and economical use of communications resources is a major challenge.

6. Synthetic Environments: *Key Technology Areas*

SYNTHETIC ELECTRONIC BATTLEFIELDS

1. Computers
2. Software
3. Sensors
4. Communications Networking
6. Environmental Effects
11. Human-System Interfaces

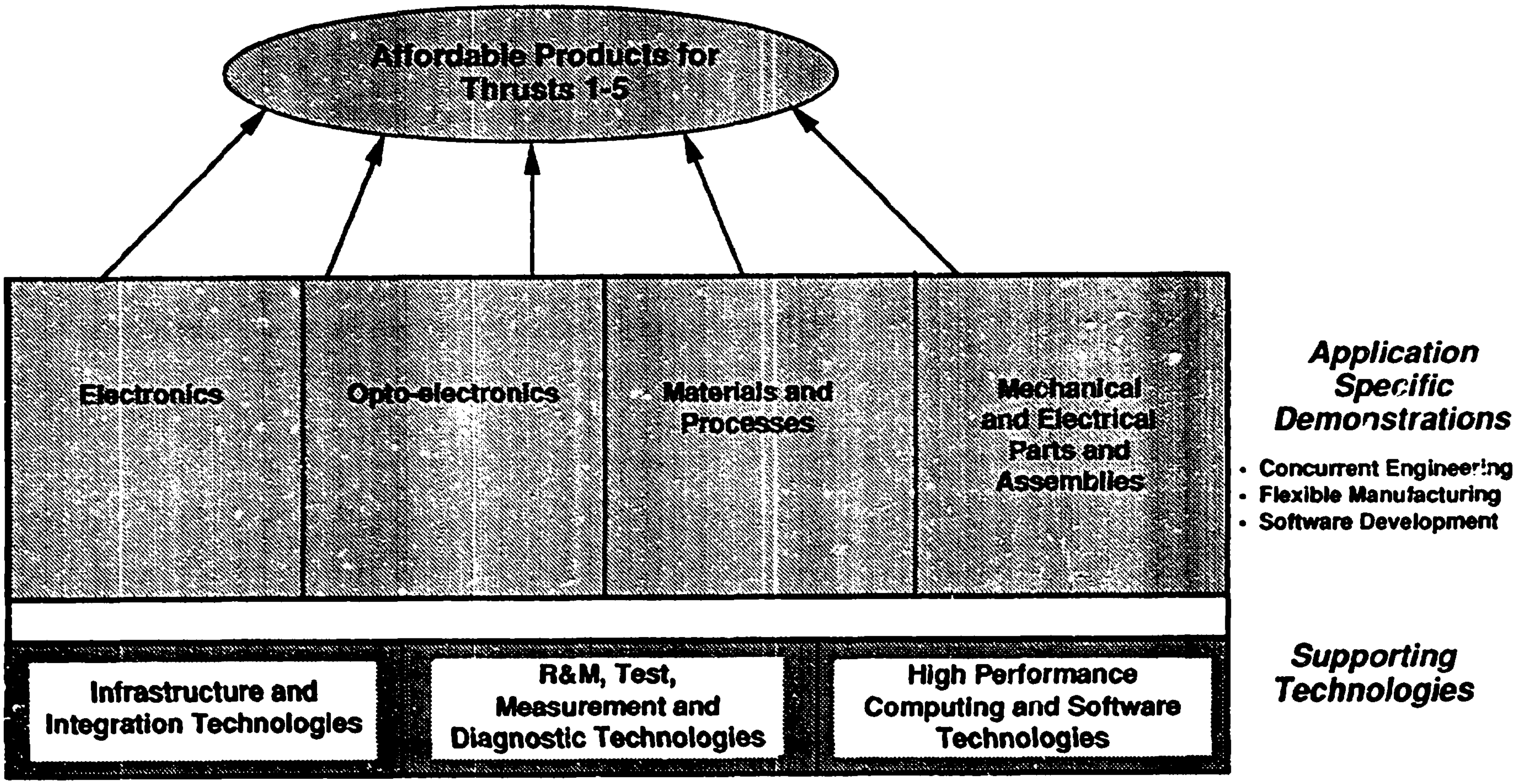
ENTRY MECHANISMS

1. Computers
2. Software
4. Communications Networking
10. Design Automation
11. Human-System Interfaces

CONNECTIVITY

1. Computers
2. Software
4. Communications Networking

7. Technology for Affordability



7. Technology for Affordability: *Legacy*

The legacy of investments in Technology for Affordability will be a new mode of defense manufacturing:

- Intelligent design tools and collaboration environments will make concurrent engineering by multidiscipline design teams the norm, and product and process designs will be captured as comprehensive computer models and transferred, error-free, to drive rapid prototyping and production.
- Unit costs will be largely independent of quantity through flexible manufacturing systems that can rapidly change from one product to the next.
- Scalable production processes with high yields will be developed early in exploratory development (6.2) and advanced development (6.3A) programs and will be supported in production by advanced equipment and intelligent process control systems.
- Information systems throughout the manufacturing enterprise will be integrated, and high speed networks will link prime contractors with customers and suppliers. The resulting data fusion and on-line real-time management control will reduce inefficiencies and exert strong leverage on the overhead burdens that drive over 50 percent of today's product costs.
- Test, measurement, and diagnostics will reduce the maintenance and ownership costs of products.

The benefits of this new mode of manufacturing will extend throughout the product life cycle, as the designed-in reliability, maintainability, producibility, and environmental considerations result in reduced maintenance, spares, and disposal costs.

7. Technology for Affordability: *Legacy*

Today	*2000-2005: Potential Via S&T*
• Slow transition to production; immature processes	• Integrated product and process development • Rapid, error-free transition to production
• Low volume implies high cost	• Flexible manufacturing systems; unit costs insensitive to lot size
• Dependence on low yield production of critical components	• Precision equipment; intelligent process control with high yields
• Activities above the factory floor drive costs	• Overhead costs controlled by integrated industrial C3 systems
• High maintenance costs	• Reduced maintenance costs, longer product life

II-7-1

7. Technology for Affordability: *Functions and Goals*

Technology for Affordability includes four basic functions.

Process Technology. The first function is the development of process technology as an integral part of new product technology development. The goal is to change the expectations in the exploratory development (6.2) and advanced development (6.3A) programs. Exit criteria will be established for each program to demonstrate scalable production processes *before* technologies are transitioned into engineering and manufacturing development (EMD).

Concurrent Engineering. The second function is the area of concurrent engineering. The idea here is to invest in intelligent design tools, collaboration technology, and shared product and process knowledge base technologies to facilitate integrated product and process design. Case studies have shown that concurrent engineering can achieve 30 percent reductions in development time, commensurate reductions in development costs, and fewer errors and downstream changes in production.

Manufacturing Processes. The third function involves factory floor manufacturing processes, where today's problems include expensive low volume production and low yields for critical components. The first goal here is to develop flexible manufacturing systems that can make rapid prototypes and production items in small lots, at unit costs approaching those of mass production. The "programmable factories" will be driven by product and process models from the concurrent engineering environment that have been debugged in advance in "virtual factory" simulators.

The second goal at the factory floor level is to develop low-cost, high-precision equipment that can dramatically improve the productivity and yields of critical processes. Programs like Sematech and the Infrared Focal Plane Array technology demonstrator are showing that this goal is achievable.

Manufacturing Functions Above the Factory Floor. The last area consists of the functions above the factory floor level—production control, inventory management, supplier and customer interface, and a host of manufacturing overhead functions. Today these functions account for over 60 percent of the costs of a complex product. Industrial C3, data fusion, and electronic commerce technologies will support the goal of cutting these overhead burdens by a factor of two or more.

7. Technology for Affordability: *Functions & Goals*

Functions	*Goals*
• Balanced product and process technology development	• Demonstrations of scalable production in 6.2 and 6.3A
• Concurrent engineering capabilities	• 30% reduction in development time; error-free transition to production
• Factory floor systems	• Make cost independent of volume • Double productivity and yield in high precision processes
• Integration above the factory floor	• Reduce overhead burdens by half

II-7-2

7. Technology for Affordability: *Top-Level Demonstrations*

The strategy for the Technology for Affordability Thrust demonstrations involves:

- Developing an overall strategic framework for next-generation defense development and production processes, as indicated by the Legacy and Functions and Goals charts.
- Developing role-model demonstrations of the next-generation capabilities, targeted on key needs of the first five Thrusts.
- Evolving an increasingly capable legacy of information infrastructure and reusable components to support expansion of the capabilities to other DoD applications.

Highlights of the specific top-level demonstrations are:

- An FY 1993 new start in the rapid design and manufacturing of application specific signal processors, which are critical components for the other Thrusts. This demonstration will show the feasibility of extending "on-demand" custom design, rapid prototyping, and efficient low volume production capabilities from individual components to complete subsystems. Annual upgrades in the packaging technologies and manufacturing processes will keep the products of this pilot factory on a steep performance growth curve.
- An FY 1993 new start in the flexible manufacturing of infrared focal plane arrays and sensor packages, which are essential to the affordability of other Thrusts. This flexible factory will use low-cost modular equipment ("cluster tools"), a wafer casette process that eliminates the need for a clean room, and intelligent manufacturing process control systems. Demonstrations will show the feasibility of affordable high-yield, low-volume production on a schedule that meets the needs of the other Thrusts.
- Additional proposed ATDs include concurrent engineering and flexible manufacturing of affordable fiber optic gyros, advanced optical materials for infrared domes and windows, advanced near net shape processes for metals and composites, affordable guidance and control assemblies, and the infrastructure and integration technologies that make Technology for Affordability demonstrations interoperable and reusable.

7. Technology for Affordability: *Top-Level Demos*

92 | 94 | 96 | 98 | 00

ATR: Automatic Target Recognition
IR: Infrared
MIMIC: Millimeterwave and Microwave Monolithic Integrated Circuits
MMST: Microelectronics Manufacturing Science and Technology

ONGOING PROGRAMS

MIMIC

Sematech, MMST, Flexible Microelectronics Manufacturing

Demos of Tools, Processes, and Affordable Components

NEW STARTS (FUNDED)

Pilot Flexible Factories for Signal Processors, IR Focal Plane Arrays

Rapidly Prototyped Application Specific Signal Processors (RASSP): Tools & Libraries; Flexible Production (Annual Upgrades); ATR Sig. Processor; Scalable Production, Multiple Applications

IR Focal Plane Arrays (IRFPA): Dewar/Cooler Demo; Med. Wave, Long Wave Flexible Manufacturing; Automated Fabrication Process Control

ADDITIONAL DEMO CANDIDATES

Pilot Flexible Factories for Affordable Radar Arrays, Gyros, Guidance & Control, Advanced Materials

Domain-specific demonstrations of engineering tools, manufacturing process and equipment, and affordable components

Infrastructure For Affordability

Interface Standards; Workstation Frameworks; Factory Sim Frameworks; Network Services; Factory C3 Architecture; Cooperative Networks; Integrated Engineering & Production Frameworks

7. Technology for Affordability: *Key Technology Areas*

The facing page shows the most important Key Technology Areas for each of the four basic functions of the Technology for Affordability Thrust: balanced product and process technology development, concurrent engineering capabilities, factory floor systems, and integration above the factory floor.

Product-Process Technology Balance. The objective here is to deliver new product technologies and scalable process technologies for production and life cycle support. The key technologies required include electronic devices and materials that avoid expensive mechanical assembly and mechanical failure modes; materials and processes for the efficient production of mechanical, electrical, and optical components and assemblies; and design automation to ensure that processes are scalable and designs can be transitioned rapidly and accurately into EMD and production.

Concurrent Engineering Capabilities. The effective, efficient, and repeatable execution of concurrent engineering on large-scale and complex projects requires automated support. This automation will be based on new generations of high performance computers, evolvable software systems, and high capacity communications networks. These technologies will be combined to provide new cooperative modes of design for products and their related processes, encouraging cross-disciplinary explorations and trade-offs that currently rae infeasible. Design reuse technology is essential, including representation, composition, archiving, and retrieval. A better understanding of human-system interfaces is important, since automation-supported cooperative design is itself a complex system involving humans and machines.

Factory Floor Systems. Programmable, flexible factories for critical products require advances in computer and software technologies to allow for the rapid and efficient management of change. Software technologies and design automation must include product and process representation technologies that can be used to drive the factories. Advanced materials processing must include synthesis, processing, and analysis based on an improved understanding of the physics involved. Communications networking, both within the factory and as a connection to the rest of the enterprise, is important in order to program, monitor, and control factory operations. These operations include rapid reconfiguration, product and process data, integrated control, incremental on-line planning and inventory control, intelligent feedback and feed-forward control, and factory simulation. Design automation is critical for dynamic process planning and to allow concurrent engineering based on new flexible production capabilities. New levels of human-system interface capabilities are needed for the efficient, error-free control of flexible, programmable factories.

Integration Above The Factory Floor. This kind of integration is essentially a very large-scale command, control and communications (C3) problem. Solutions will depend on advances in computer, communications, and software technologies applied to inter-company enterprise integration. Technologies must be developed to allow for the flexible and efficient formation of product-process teams, both within and among companies.

7. Technology for Affordability: *Key Technology Areas*

PRODUCT-PROCESS TECHNOLOGY BALANCE

5. Electronic Materials and Devices
7. Materials and Processes
10. Design Automation

CONCURRENT ENGINEERING CAPABILITIES

1. Computers
2. Software
4. Communications Networking
10. Design Automation
11. Human-System Interfaces

FACTORY FLOOR SYSTEMS

1. Computers
2. Software
4. Communications Networking
7. Materials and Processes
10. Design Automation
11. Human-System Interfaces

INTEGRATION ABOVE THE FACTORY FLOOR

1. Computers
2. Software
4. Communications Networking
10. Design Automation
11. Human-System Interfaces

GLOSSARY

GLOSSARY

ALS	Air/Land/Sea
ASARS	Advanced Synthetic Aperture Radar System
ASW	Anti-Submarine Warfare
ATACMS	Advanced Tactical Missile System
ATARS	Advanced Tactical Airborne Reconnaissance System
ATD	Advanced Technology Demonstration
ATM	Asynchronous Transfer Mode
ATR	Automatic Target Recognition
AWACS	Airborne Warning and Control System
BDA	Battle Damage Assessment
BM	Battle Management
CAC2	Combined Arms Command & Control
CAV	Composite Armored Vehicle
CCD	Camouflage, Concealment, and Deception
CEP	Circular Error of Probability
CGS	Common Ground Station
CINC	Commander in Chief
CLO	Counter-Low Observables
CM	Cruise Missile
CONUS	Continental United States
C2	Command and Control
C3	Command, Control, & Communications
C3I	Command, Control, Communications, and Intelligence
CVC2	Combat Vehicle Command and Control
DARPA	Defense Advanced Research Projects Agency
DemVal	Demonstration/Validation
DDR&E	Director of Defense Research and Engineering
DDD&E(S&T)	Deputy Director of Defense Research and Engineering (Science and Technology)
EHF	Extremely High Frequency
EMD	Engineering and Manufacturing Development
EO	Electro-Optical
ERINT	Extended Range Interceptor
FLIR	Forward Looking Infrared Radar

FMBT	Future Main Battle Tank
FOG-M	Fiber Optic Guided Missile
FPA	Focal Plane Array
GBR	Ground-Based Radar
GPS	Global Positioning System
GRCS	Guardrail Common Sensor
HIMARS	High Mobility Artillery Rocket System
HMMWV	High Mobility Multipurpose Wheeled Vehicle
ICBM	Intercontinental Ballistic Missile
IFDL	Intra-Flight Data Link
IFF	Identification Friend or Foe
IR	Infrared
IRST	Infrared Search and Track
IR&D	Independent Research & Development
JDL	Joint Directors of Laboratories
JPS	Joint Precision Strike
JSTARS	Joint Surveillance and Target Acquisition Radar System
JTFC	Joint Task Force Commander
JPO	Joint Program Office
KTA	Key Technology Area
LCV	Light Contingency Vehicle
LOS	Line-of-Sight
MCM	Mine Countermeasure
MIMIC	Millimeterwave and Microwave Monolithic Integrated Circuits
MLS	Multilevel Secure
MMST	Microelectronics Manufacturing Science and Technology
MMW	Millimeterwave
MTK	Masked Target Kill
NDI	Non-Developmental Item
NLOS	Non-Line-of-Sight
OC	Optical Carrier
PGM	Precision Guided Munition
Pk	Probability of kill
PS	Precision Strike
R&D	Research and Development
R&M	Reliability and Maintainability
RASSP	Rapidly Prototyped Application Specific Signal Processors
RJ	River Joint

RPV	Remotely Piloted Vehicle
S&T	Science and Technology
SAFOR	Semi-Automated Forces
SDIO	Strategic Defense Initiative Organization
SIGINT	Signals Intelligence
SLCM	Submarine Launched Cruise Missile
SOF	Special Operations
SONET	Synchronous Optical Network
TACAWS	The Army Combined Arms Weapons System
TBM	Tactical Ballistic Missile
TBMD	Tactical Ballistic Missile Defense
THAAD	Theater High Altitude Defense
TLAM	Tomahawk Land Attack Missile
TV	Television
UAV	Unmanned Air Vehicle
UAV-SR	Unmanned Air vehicle—Short Range
USW	Undersea Warfare
UW	Ultrawide Band
UUV	Unmanned Undersea Vehicles
VIDS	Vehicle Integrated Defense System
WARSIM	Wargaming Simulation
WAS	Wide Area Surveillance